SECTION 4

HYDRAULIC DISCHARGE MEASUREMENTS ON THE ST. CLAIR RIVER

4.1 North, Middle and South Channels, 1856.

Sherman Moore, in a 1933 unpublished Lake Survey report, noted that the first record of St. Clair River flows appeared on a chart, which no longer exists, of the St. Clair Flats, dated 1857. The flow through the North Channel was marked 99,500 cfs, that through the Middle Channel 31,400 cfs and that through the South Channel 81,500 cfs, making a total flow of 212,400 cfs. These values appeared to be the results of measurements made October 4 to 10, 1856; no other record of these measurements could be found. Using observed elevations at Milwaukee, Wisconsin, and at Port Colbourne, Ontario, for the month of October 1856, and correcting them for the tilt of the earth, Sherman Moore went on to compute the flow of the river using an equation developed for the period before 1900. The resulting October 1856 flow was 224,400 cfs. Assuming that the flow through Chenal Ecarté, which was not measured, was six percent of the total, as determined in 1910, and that the flow in the South Channel, as measured, included the flow through the Bassett Channel, the total river flow becomes 225,900 cfs, which is only 0.7 of one percent more than Moore's computed flow. This remarkable check is of course purely accidental, but it gives evidence that there was no great change in the regimen of the river between 1856 and 1899.

4.2 Discharge Measurements near St. Clair, Michigan, 1867-1868.

4.2.1 Purpose.

In 1867, D. Farrand Henry, of the U.S. Lake Survey, Corps of Engineers, using double floats, measured the St. Clair River flow at a section near the City of St. Clair, Michigan. Experience gained in this work with floats convinced Henry that their use gave results as much as ten percent too large. In 1868, measurements were made using current meters, designed and built by Henry. Both of these sets of measurements were part of a larger project to measure the flows in the Great Lakes connecting channels. Measurements were also made on the St. Marys River, in 1867, and on the Niagara and St. Lawrence Rivers in 1867 and 1868.

4.2.2 Description of Section.

In 1867, a section was established near the City of St. Clair, Michigan. This section consisted of two section lines, 700 feet apart. The section lines were divided into eight panels. Between June 20 and July 19, 1867, 73 discharge measurements were made. In 1868, a single section line, in the same general location, was used. This section was also

divided into eight panels. The measuring stations were approximately 200 feet apart. In 1868, 44 discharge measurements were made, during the period June 27 to September 17. See Figure 2-7 for the location of the City of St. Clair, Michigan.

4.2.3 Measurement Techniques.

In 1867, under the direction of D. Farrand Henry, determination of the discharge of the St. Clair River was made by means of double floats. Subsection 3.1.3 (St. Marys River, 1867) details the method used. In summary, two section lines were established and sounded, and the movement of floats past these sections were observed. The floats were set in the river with the lower part at various depths and the points, where each float crossed the upper and lower sections, together with the time required for passage, were recorded. Velocities were observed at each five feet of depth.

In 1868, discharge measurements were made using newly devised electrical recording current meters, designed from anemometers. A description of these meters can be found in the Report of the Chief of Engineers, 1869, page 565. A meter was lowered into the water, causing a set of cups attached to an axis to spin as the water passed. An electric device would record the number of revolutions of the cups, as they completed an electric circuit on each full revolution. The meters were rated often; before, during and after a series of measurements, in order to determine a conversion from revolutions per unit of time to velocity in feet per second.

Velocity measurements were made across the section, at points 200 feet apart. To determine the vertical distribution of the velocity, measurements were made at each 5 feet of depth. Only a few positions were occupied in a day. Several attempts were made to measure the entire section in one day. This was accomplished by only measuring at two or three depths at each station.

No record of water surface elevations was kept, except those on the section.

4.2.4 Discharge Computation.

Reduction of 1867 Measurements. The soundings of the two cross sections were averaged to obtain a mean cross section. This mean cross section was divided into eight panels, and an area was computed for each.

The actual distance each float traveled in passing between the sections, as determined from the angles from the base line recorded by the observers, divided by the time required for passage, gave the velocity of the river at that depth and place on the mean section. The daily panel discharge was determined by multiplying the panel area, corrected for stage, by the mean velocity of all the floats that passed through the panel during the day. These daily panel discharges were tabulated and their mean gave the panel discharge for the period. The discharge of the river for the period was obtained by adding together the eight panel

discharges. This value, as determined by Henry, gave the discharge of the river as 233,726 cfs for the period June 20 through July 19, 1867.

1869 Reduction of 1868 Measurements. Velocity curves were constructed by plotting all the velocities measured at each five feet of depth at each measuring station. From these curves, the velocity measured at each five feet of depth of a panel was reduced to a mean velocity for each panel for a particular measurement. The mean velocity measured in a panel for a particular measurement was multiplied by the panel area, derived from soundings and water level readings, to obtain the discharge through the panel.

The discharge through the entire section was computed by finding the ratio between the mean discharge of each panel for all measurements and that of the whole river, and then multiplying the discharge found in any panel by this ratio. Discharges computed only from side panels were not considered accurate. Table 4.1 (see Appendix C) summarizes the discharge measurements of 1868, as reduced by Henry.

1947 Reduction of 1868 Measurements. The 1868 measurements were recomputed by the U.S. Lake Survey, in 1947, using computation methods in use at the time. Using the observed velocities at five-foot depths and soundings from the 1868 measurements, a profile of each river section was drawn and divided into panels. Panel areas were determined and these areas represented the average condition during the period of observations. Velocities observed in each panel were tabulated. Means of each five-foot depth were taken and reduced to 0.4 depth velocities, according to the vertical velocity curve as determined on the St. Clair River in 1944. The 0.4 depth velocities were plotted and a transverse velocity curve was drawn. From this curve, velocities for mid-panel at the 0.4 depth were determined. These mid-panel 0.4 depth velocities were reduced to mean panel velocities, using coefficients derived from the vertical and transverse velocity curves. The product of the mean panel velocity and panel area gave the average panel discharge during the period of observations. The sum of the panel discharges gave a total river average discharge of 221,600 cfs for the period, as compared to an average of 216,300 cfs computed by Henry.

Henry's report on the measurements made in 1867 is given in the Report of the Chief of Engineers of 1868, page 949. The report on the 1868 measurements is in the Report of the Chief of Engineers of 1869, page 563. The 1947 reduction of the 1868 measurements is documented in file 3-3100 of the U.S. Lake Survey Archives (available at the U.S. National Oceanic and Atmospheric Administration/National Ocean Service, Silver Springs, Maryland).

4.3 Dry Dock and Craig Sections, 1899-1902.

4.3.1 Purpose.

In order to measure the total flow in the St. Clair River, the U.S. Lake Survey District, Corps of Engineers, established, in 1898, a hydraulic section on the river just below

the confluence of the Black River. In 1899, the first discharge measurements were made at this section. Measurements continued to be made in 1900, 1901 and 1902.

4.3.2 Description of Sections.

The **Dry Dock Section** was established in 1898. Located about 2-1/2 miles below the mouth of the Black River, the section extended across the river from the U.S. to the Canadian shore. The section was divided into 21 panels with the metering stations located 100 feet apart. A series of 90 measurements were made at this section, between April 29 and December 6, 1899. An additional 78 measurements were made between June 19, 1900 and February 2, 1901. Between January 2 and February 2, 12 measurements were made, while the channel was partially blocked with ice. When ice in the river extended up to this section, in early February, another section was established further upstream.

A new section, the **Craig Section**, was also located below the mouth of the Black River, and stretched from a dock on the U.S. shore at the foot of Baird Street, Port Huron, Michigan, to a lumber dock in Sarnia Bay, Ontario, on the Canadian shore. For this survey the section was divided into 13 panels. Between February 4 and March 23, 1901, 32 discharge measurements were made at this section.

When the ice field began to recede back downstream, measurements were again made at the Dry Dock Section. Seventeen measurements were made between March 25 and April 26, 1901, before the blockage finally broke. Between May 14 and June 28, 1901, 36 additional measurements were made. Work at the Dry Dock Section continued in 1902, and 32 measurements were made between August 12 and September 26.

The location of the Black River can be found on Figure 2-7, which depicts the St. Clair River. An estimated location of the Dry Dock Section, at that time, can be found on Figure 4-1. Indications are that the Craig Section was located about a mile below the mouth of the Black River, but this cannot be substantiated.

4.3.3 Measurement Techniques.

The sections were lead-line sounded and section profiles were developed, from which base panel areas were computed. Vertical velocity measurements were made in 1899, using a multiple meter set. This consisted of eleven velocity meters, one above another, suspended in gimbals between two steel cables, and held in place by a heavy weight on the bottom. With this device, the velocities at each tenth of depth were observed simultaneously. When discharge measurements were made, velocity readings were taken only at the 0.5 depth of each panel of the Dry Dock Section. Measurements were taken only at the 0.4 depth of each panel on the Craig Section.

Water levels were recorded at the Fort Gratiot, Grand Trunk Railroad, Mouth of the Black River and Dry Dock gauges. The Fort Gratiot gauge, was an analog recording gauge.

It was installed in 1899 in a well, about 650 feet north of the Fort Gratiot Lighthouse. The pipe leading to the well became clogged with sand and the gauge was discontinued in September 1900. During this discharge survey and for a short time after, staff gauge readings were used. The Grand Trunk Railroad gauge was a self-registering gauge, installed in 1899 at the Grand Trunk Railroad ferry slip, about 3,600 feet below the Fort Gratiot Lighthouse. The gauge at the Mouth of the Black River was a self-recording gauge, installed in December 1900, at a point about 600 feet north of the north side of the Black River, in Port Huron, Michigan. In February 1899, a self-registering gauge was established at the Danford and Alverson Dry Dock, about 2 miles below the mouth of the Black River. On July 28, 1900, the Dry Dock gauge was moved about 1,500 feet downstream to the foot of Grant Place, at the end of the Dry Dock Section.

Listed below are the controlling bench marks for the water level recording gauges referenced, and the elevation of these bench marks.

Water Level Gauge	Controlling Bench Mark	Bench Mark Elevations (feet) 1903 Datum
Fort Gratiot	Fort Gratiot Lighthouse	590.34
Grand Trunk RR.	39A	588.43
Mouth, Black R.	I	585.36
Dry Dock	17	596.73

4.3.4 Discharge Computation.

Vertical velocity measurements were made at both the Dry Dock (1899) and Craig (1901) Sections. Vertical velocity curves and coefficients were developed to convert the velocities measured at the index point (0.5 or 0.4 depth) to a mean velocity for the panel.

To determine the panel discharge for a measurement, the observed velocity in the panel was multiplied by the vertical velocity coefficient for the panel to get an average panel velocity. This velocity was then multiplied by the panel area (adjusted for actual water elevations) to get the discharge through the panel. The discharge through the section was the sum of panel discharges for that measurement.

A summary of the measured discharges is given in Tables 4.2 to 4.7 (see Appendix C). The recovered data related to this survey can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, files numbered 3-1407, 3-1473 and 3-1469, of the Detroit District, Corps of Engineers, Detroit, Michigan.

4.4 Dry Dock and Gorge Sections, 1908-1909.

4.4.1 Purpose.

In hearings before a referee on the case of the United States vs. the Sanitary District of Chicago, the accuracy of the discharge measurements made by the U.S. Lake Survey District was questioned. For the purpose of substantiating the past flow measurements of the St. Clair River, a new hydraulic section, the Gorge Section, was established. In 1908, discharge measurements were made at both the Gorge Section and the previously established Dry Dock Section. These discharge measurements were also made to ascertain whether or not there had been any change in the regimen of the St. Clair River; that is, since measurements were last made in 1901.

All work for this series of measurements was done by personnel from the U.S. Lake Survey District, Corps of Engineers.

4.4.2 Description of Sections.

The **Dry Dock Section,** first established in 1898, was re-established about 5 to 7 feet from its previous location due to difficulty recovering the old range targets. Located about 2-1/2 miles below the mouth of the Black River, the section extended across the river from the U.S. to the Canadian shore. The section was divided into 19 panels for both the 1908 and 1909 surveys. Fifteen discharge measurements were made between November 7 and 18, 1908. Twenty-four measurements were made during the period November 15 to December 7, 1909, but three of these were later dropped, due to inconsistencies in the meter readings.

The **Gorge Section** was established for this survey to serve as a check on the Dry Dock Section flow measurements. Located near the narrowest point on the main channel, with higher current velocities and greater depths, it was felt that flow measurements at the Gorge Section would be more accurate, and would permit measurements in a much shorter periods of time. The section was located 500 feet above the narrowest point in the river, about 1,400 feet below the Fort Gratiot Lighthouse and about 1,250 feet above the foot of State Street. The section, 1,020 feet wide (220 feet wider than the narrowest part of the river), was divided into ten panels. Twenty-two measurements were made between November 18 and December 19, 1908 and 38 between October 15 and December 10, 1909.

The locations of these discharge measurement sections are shown on Figure 4-1.

4.4.3 Measurement Techniques.

Both sections were lead-line sounded prior to both the 1908 and 1909 measurements. Vertical velocity measurements were made at each panel of the Gorge Section, during both periods of measurement. In 1908, the direction of flow at the Gorge Section was deter-

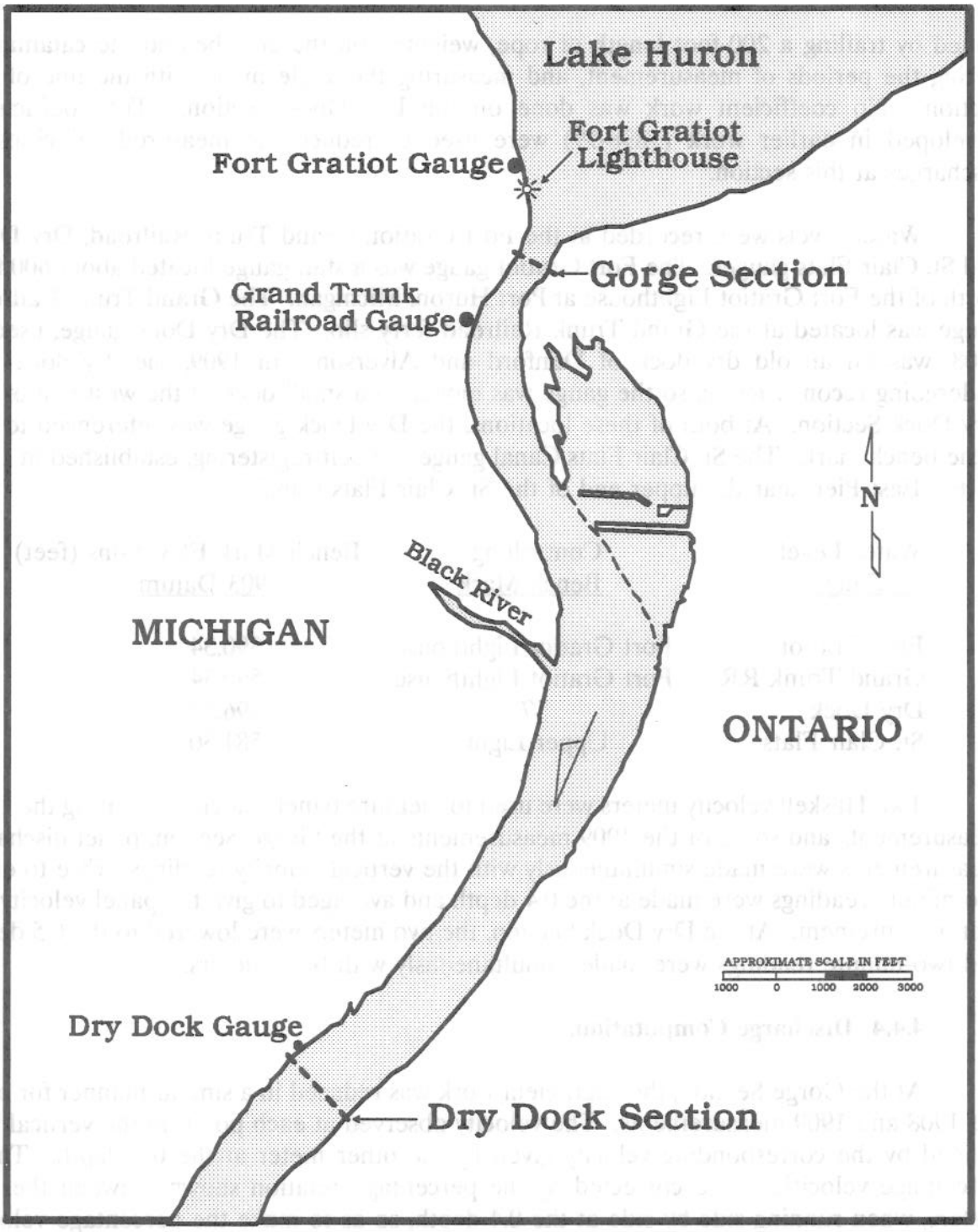

Figure 4-1

St. Clair River, 1908-1909 Dry Dock and Gorge Section Locations

mined by trailing a 200-foot length of rope, weighted on the end, behind the catamaran, during the periods of measurement, and measuring the angle made with the line of the section. No coefficient work was done on the Dry Dock Section. The coefficients developed in earlier work (1898-99) were used to reduce the measured velocities to discharges at this section.

Water levels were recorded at the Fort Gratiot, Grand Trunk Railroad, Dry Dock and St. Clair Flats gauges. The Fort Gratiot gauge was a staff gauge located about 600 feet north of the Fort Gratiot Lighthouse at Port Huron, Michigan. The Grand Trunk Railroad gauge was located at the Grand Trunk Railroad ferry slip. The Dry Dock gauge, used in 1908, was on an old dry dock of Dunford and Alverson. In 1909, the dry dock was undergoing reconstruction, so the gauge was moved to a small dock at the west end of the Dry Dock Section. At both of these locations, the Dry Dock gauge was referenced to the same bench mark. The St. Clair Flats Canal gauge was self-registering, established in 1906 on the East Pier near the upper end of the St. Clair Flats Canal.

Water Level Gauge	Controlling Bench Mark	Bench Mark Elevations (feet) 1903 Datum
Fort Gratiot	Fort Gratiot Lighthouse	590.34
Grand Trunk RR.	Fort Gratiot Lighthouse	590.34
Dry Dock	17	596.73
St. Clair Flats	Upper Light	581.30

Two Haskell velocity meters were used to measure panel velocities. During the 1908 measurements and some of the 1909 measurements at the Gorge Section, panel discharge measurements were made simultaneously with the vertical velocity readings. Five to eight two-minute readings were made at the 0.4 depth and averaged to give the panel velocity for that measurement. At the Dry Dock Section, the two meters were lowered to the 0.5 depth and two-minute readings were made, simultaneously with both meters.

4.4.4 Discharge Computation.

At the Gorge Section, the coefficient work was reduced in a similar manner for both the 1908 and 1909 measurements. The velocity observed at each point on the vertical was divided by the corresponding velocity given by the other meter at the 0.4 depth. These percentage velocities were corrected by the percentage relation shown between the two meters, when running side by side at the 0.4 depth, so as to make the percentage velocity at the 0.4 depth equal to 100. The mean of all observations on each point were then plotted and a smooth curve was drawn through them. The mean ordinate to this curve was the vertical velocity coefficient for the station. It is assumed that this coefficient is constant for all points in the panel. The mean velocity at each index point was computed and the results divided by the weighted mean index velocity for the section. These percentage velocities were then plotted and through them was drawn the transverse velocity curve at the 0.4

depth. The transverse coefficients were calculated as the mean ordinate to the transverse velocity curve in each panel, divided by the ordinate at the station. The direction coefficient was the cosine of the angle between the direction of the current and a normal to the section. The velocity coefficient for each panel was the product of the vertical, the transverse and the direction coefficients.

The coefficient observations of 1909 were reduced independently of those of 1908 and compared. Except at the end panels, the individual coefficients compared very favorably. The weighted mean velocity coefficient from the work of 1909 checked exactly with that derived from the work of 1908. Because of this, the observations of the two seasons were combined and a final set of coefficients was determined for use in reducing the 1909 discharges.

As previously mentioned, coefficients developed in 1899 were used to reduce the discharges at the Dry Dock Section for both the 1908 and 1909 surveys. At both sections, for both series of measurements, the discharge of each panel was the product of the velocity measured at the index point (0.4 or 0.5 depth at the midpoint of the panel), the velocity coefficient and the area of the panel, as determined by the reading of the section gauge. The discharge through the section was the sum of the discharges in the panels.

Tables 4.8 to 4.11 (see Appendix C) summarize the discharges made at the Dry Dock and Gorge Sections in 1908 and 1909. The reports documenting these surveys can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file 3-1929, of the Detroit District, Corps of Engineers, Detroit, Michigan.

4.5 Gorge, Dry Dock, SNY, Bridge, Bassett, Southeast Bend, Middle Channel and Salt Block Sections, 1910.

4.5.1 Purpose.

In order to determine the distribution of flow through the various channels of the St. Clair River delta, and to ascertain whether the distribution among the channels varied with the seasons, the U.S. Lake Survey District, Corps of Engineers, undertook a survey of eight hydraulic sections on the St. Clair River, in 1910.

It should be noted that, during the measurement season, there was an unusually small variation in stage and slope; also, dredging of sand and gravel was in progress. This could have seriously affected the flow-stage relationship.

4.5.2 Description of Sections.

First established in 1908, the **Gorge Section**, located at the head of the St. Clair River above the confluence of the Black River, measured the outflow from Lake Huron. The section extended from the U.S. shore at Port Huron, Michigan, to the Canadian shore at

Point Edward, Ontario. From May 9 to November 11, 1910, a total of 148 discharge measurements were made at this section.

The **Dry Dock Section** measured the total river flow, including the inflow from the Black River. The section extended across the river, from the U.S. to the Canadian mainland, about 2-1/2 miles below the Black River. A series of 44 discharge measurements were made between June 22 and October 1, 1910; two of these measurements were later rejected.

The **SNY Section** was located on the Chenal Ecarté, just below Marshy Creek and about 3/4 mile below the main channel of the St. Clair River. Extending from Walpole Island to the Canadian mainland, the section was divided into 7 panels from south to north. Between May 25 and November 25, 1910, 20 discharge measurements were made.

The **Bridge Section** extended across the head of the South Channel of the St. Clair River and stretched from the west shore of Walpole Island to the east shore of Russell Island. The section was divided into 7 panels. Eighteen measurements of the total South Channel flow were made during the period May 26 to November 25, 1910.

In 1910, the South Channel split into two smaller channels, the Southeast Bend and Bassett Channels; the present St. Clair Cutoff had not yet been excavated. For this survey, a hydraulic section was established on both channels. The **Southeast Bend Section** extended from Bassett Island to Harsens Island, across the Southeast Bend. The **Bassett Section** was located near the head of the Bassett Channel and ran from Bassett Island northeast to Squirrel Island.

The Southeast Bend Section was divided into 8 panels and 19 measurements were made between June 2 and November 26, 1910. Nineteen measurements were also made on the 6 panels of the Bassett Section, but not simultaneously.

The North Channel of the St. Clair River divides around Dickinson Island. A hydraulic section was established on both the North Channel and the Middle Channel. The **Salt Block Section** traversed the North Channel from Dickinson Island to the Michigan mainland. The section was divided into 9 panels and 21 measurements were made between June 4 and November 22, 1910. The **Middle Channel Section** extended across the Middle Channel from Dickinson Island to Harsens Island. It was divided into 7 panels and 20 measurements were made at the section between May 28 and November 19, 1910.

The locations of these discharge measurement sections are shown on Figure 4-2.

4.5.3 Measurement Techniques.

Each section was lead-line sounded and cross section profiles were produced, from which panels and panel areas were determined. Direction of flow surveys were also carried

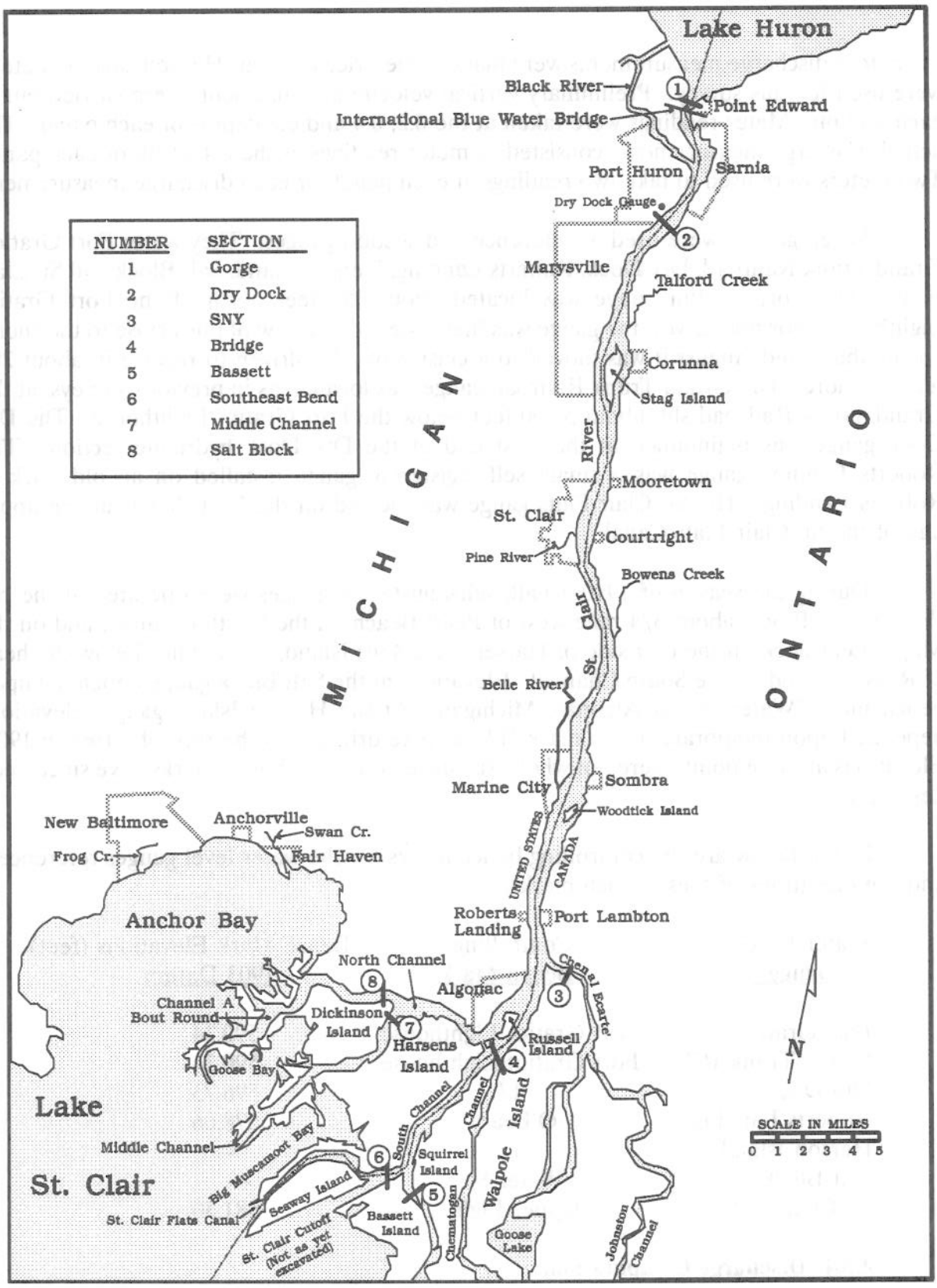

Figure 4-2

St. Clair River, 1910 Section Locations

out before discharge measurements were made. One Price and four Haskell current meters were used for this survey. Preliminary vertical velocity measurements were carried out at each section. Meter readings were taken at the 0.2, 0.4 and 0.8 depths of each panel. The actual discharge measurements consisted of meter readings at the 0.4 depth of each panel. Two meters were used to take two readings at each panel for each discharge measurement.

Seven gauges were used as reference and section gauges. They were: Fort Gratiot, Grand Trunk Railroad, Dry Dock, Roberts Landing, Herson Island, Salt Block and St. Clair Flats. The Fort Gratiot gauge was located about 650 feet north of the Fort Gratiot Lighthouse. For this survey, the gauge was first fastened to a row of piles close to the shore, but in about mid August it was moved to a cluster of piles driven to receive it, about 200 feet off shore. The Grand Trunk Railroad gauge was located, as in previous surveys, at the Grand Trunk Railroad slip about 3,600 feet below the Fort Gratiot Lighthouse. The Dry Dock gauge was maintained at the west end of the Dry Dock hydraulic section. The Roberts Landing gauge was a small, self-registering gauge installed on an old dock at Roberts Landing. The St. Clair Flats gauge was located on the East Pier near the upper end of the St. Clair Flats Canal.

During the season of 1910, small, self-registering gauges were operated at the old Walton Salt Block, about 3/4 mile west of Pearl Beach on the North Channel, and on the Maple Leaf dock on the east side of Harsens (Herson) Island, 7-1/2 miles below the head of Russell Island on the South Channel. Elevations at the Salt Block gauge depended upon bench mark "Water St." at Algonac, Michigan. At the Herson Island gauge, elevations depended upon temporary bench mark "12", a spike driven into the root of a tree in 1908. Elevations at these points were not wholly satisfactory and the bench marks have since been destroyed.

Listed below are the controlling bench marks for the water level gauges referenced, and the elevations of these bench marks.

Water Level Gauge	Controlling Bench Mark	Bench Mark Elevations (feet) 1903 Datum
Fort Gratiot	Fort Gratiot Lighthouse	590.34
Grand Trunk RR.	Fort Gratiot Lighthouse	590.34
Dry Dock	17	596.73
Roberts Landing	O'Leary	578.66
Herson Island	12	---
Salt Block	Water St.	---
St. Clair Flats	Upper Light	581.30

4.5.4 Discharge Computation.

Directional and vertical velocity coefficients were developed from the measurements

taken for this purpose, one set for each section. Sets of transverse velocity coefficients were developed for each section, for each of the five periods for which measurements were made. The three coefficients were multiplied together to get a combined coefficient for each panel of each section, for each of the five periods of measurement.

To calculate the discharge through a panel, first the velocity through the panel was determined. The two meter readings taken at the panel during a measurement were, in most cases, meaned to get the panel velocity for the measurement. The velocity measured in the panel was multiplied by the area of the panel and by the appropriate combined coefficient, to get the discharge in the panel. The discharge through the section was obtained by summing the individual panel discharges.

The discharge values resulting from this survey are listed in Tables 4.12 to 4.19 (see Appendix C). The recovered data related to this survey can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, files numbered 3-1477 and 3-1973, of the Detroit, District, Corps of Engineers, Detroit, Michigan.

4.6 Dry Dock Section, 1924-1930.

4.6.1 Purpose.

Several sets of discharge measurements were made at the Dry Dock Section, during the period 1924 to 1930. These measurements were obtained to provide base data for the St. Clair River stage-discharge equations. During the period 1924 to 1927, measurements were made to take advantage of the prevailing low stage conditions. During the 1924 measurements, the weather was bad and the correlation between flow and stage was not good, because the river was rarely in stable equilibrium. There was also some question with regard to the ratings of the meters.

All of the discharge measurements made during the period 1924 to 1927 were made either in early spring or late fall. Recognizing the probability of a seasonal change in the relationship between flow and slope, measurements were made every month from May through November, 1928.

In 1929, measurements were made to take advantage of unusually high water level conditions, and in 1930, measurements were made at an intermediate range of levels.

4.6.2 Description of Section.

The **Dry Dock Section,** located about 2-1/2 miles below the mouth of the Black River, was recovered from previous surveys. As in past surveys, the section was divided into 21 panels with the metering stations at the panel midpoints. See Figure 4-2 for the location of the section.

4.6.3 Measurement Techniques.

The Dry Dock Section was sounded prior to each measurement session, and panel areas were determined. The 1924 soundings differed markedly from those made in previous years, but only in a 600 foot length of the section, which encompassed panels 9 to 14. In 1925, vertical velocity measurements were made at these six panels. Vertical velocity measurements were also made at stations 7 and 16 as a check to previous measurements. Eight determinations were made using two Haskell current meters. One meter was held constant at the 0.5 depth, while the remaining meter took successive readings at each tenth depth.

In 1928, vertical velocity measurements were made at the 0.3, 0.5 and 0.7 depths of panels 3, 4, 5, 6, 8, 12, 15, 17, 18, 19 and 20. The vertical velocity curves used in 1925 were employed on the remaining panels.

In 1929 and 1930, vertical velocity measurements were again made, this time for all the panels. The vertical velocity measurements were made by keeping one meter at the 0.5 depth of the panel and using two other meters to measure velocity at the surface, near the bottom and at the 0.1, 0.3, 0.7 and 0.9 depths.

As part of the discharge program, two or three Haskell meters were suspended at the 0.5 depth of each panel and two two-minute readings were made.

Water levels recorded at the Grand Trunk Railroad, Dry Dock and Roberts Landing gauges were used in reducing the discharge measurements made at the Dry Dock Section. The Grand Trunk Railroad gauge was a self-registering gauge installed at the Grand Trunk Railroad ferry slip, about 3,600 feet below the Fort Gratiot Lighthouse.

In the Fall of 1924, a reference gauge was installed at the end of the Dry Dock Section. This gauge was referenced to bench mark "17." In July 1926, the Dry Dock gauge was moved 1,500 feet upstream to the old Danford and Alversen dry dock. This gauge was referenced to bench mark "Grate Bar."

The Roberts Landing gauge was a small, self-registering gauge installed in July 1924 on the old dock at Roberts Landing. This gauge was operated only during the summer months, until a permanent gauge was installed in November 1929. A staff gauge was read during the winter of 1924-25.

Listed below are the controlling bench marks used to reference the water level gauges and the elevations of these bench marks.

Water Level Gauge	Controlling Bench Mark	Bench Mark Elevations (feet) 1903 Datum
Grand Trunk RR.	GTR	587.90
Dry Dock	17	596.73
Roberts Landing	O'Leary	578.58

For the surveys covered in this section, the following table lists the number of measurements made during a survey and the periods during which they were made.

Dates of Survey	Number of Measurements
November 22 to December 5, 1924	12
April 18 to May 6, 1925	15
May 17 to May 26, 1926	19
April 28 to May 9, 1927	20
September 9 to September 23, 1927	20
May 23 to November 13, 1928	111
June 15 to August 22, 1929	42
August 5 to August 22, 1930	24

4.6.4 Discharge Computation.

Areas determined from each set of soundings were used to reduce that particular period's data. New vertical velocity coefficients were determined for those stations where vertical velocity measurements were made. For the other stations, the coefficients determined in previous surveys were used in discharge reduction. The difference between the vertical velocity coefficients determined in 1899 and those determined in 1925-28 was 0.23 of one percent. This check shows that after the lapse of 25 years, during which considerable change in cross section occurred, there had been little change in the coefficients.

Because the velocity across the river at the Dry Dock Section changed so slowly, transverse velocity coefficients were determined only for stations 1, 2, 3, 19, 20 and 21. Transverse velocity coefficients were calculated for each season that work was performed.

Discharges were determined by applying both the vertical and transverse velocity coefficients for a panel to the 0.5 depth velocities measured in that particular panel, and multiplying the panel area by this adjusted velocity. The discharges through each of the 21 panels were summed to give a section discharge.

The measurements made in 1926 were found to be inconsistent and were felt to be of no value. The problem was investigated in 1927. The discharges were reevaluated in

conjunction with the 1927 measurements; these reevaluated discharges are given in Table 4.22 (see Appendix C). Tables 4.20 to 4.26 summarize all the discharge measurements made at the Dry Dock Section between 1924 and 1930.

A report documenting the 1924, 1925 and 1926 measurements can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file 3-2481, of the Detroit District, Corps of Engineers, Detroit, Michigan. The report resulting from the 1927 measurements, which also contains a revision of the 1926 measurements, based on the investigation of meter abnormalities in 1927, can be found in file 3-2494 of the same Archives. The report documenting the 1928 measurements can be found in files 3-2518 and 3-2544. The data and results of the 1929-1930 survey are located in file 3-2551.

4.7 Stag Island and Woodtick Sections, 1925-1929.

4.7.1 Purpose.

Discharge measurements were made east of Stag and Fawn (Woodtick) Islands, in conjunction with the total river flow measurements at the Dry Dock Section (see Subsection 4.6). These measurements were used to determine the distribution of flow around these two islands, the only islands in the St. Clair River between the head of the river and the St. Clair Flats. In May 1925, a series of three measurements were made at the Stag Island Section. Discharge measurements were made at both the Stag Island and Woodtick Sections, during the months of May, August and October, 1928 and May 1929. Measurements were made at the Stag Island Section again in September 1929.

4.7.2 Description of Sections.

The **Stag Island Section** was established in May 1925 to measure the flow east of Stag Island. This hydraulic section was located near the lower end of the island and was divided into ten panels. At the time of the 1928 and 1929 measurements, due to higher water levels, there was no land at the western end of the section, as established in 1925. For the 1928 and 1929 surveys, the Stag Island Section was extended west to the shore of the island and divided into nine panels.

The flow east of Fawn (Woodtick) Island was measured at a section about 2,600 feet below the head of the island. The **Woodtick Section** was divided into seven panels.

The locations of these discharge measurement sections are shown on Figure 4-3.

4.7.3 Measurement Techniques.

Both sections were sounded prior to each set of discharge measurements. Vertical velocity measurements were made for each set of discharges and consisted of velocity observations at each tenth depth of the panels. Discharge measurements were taken at the

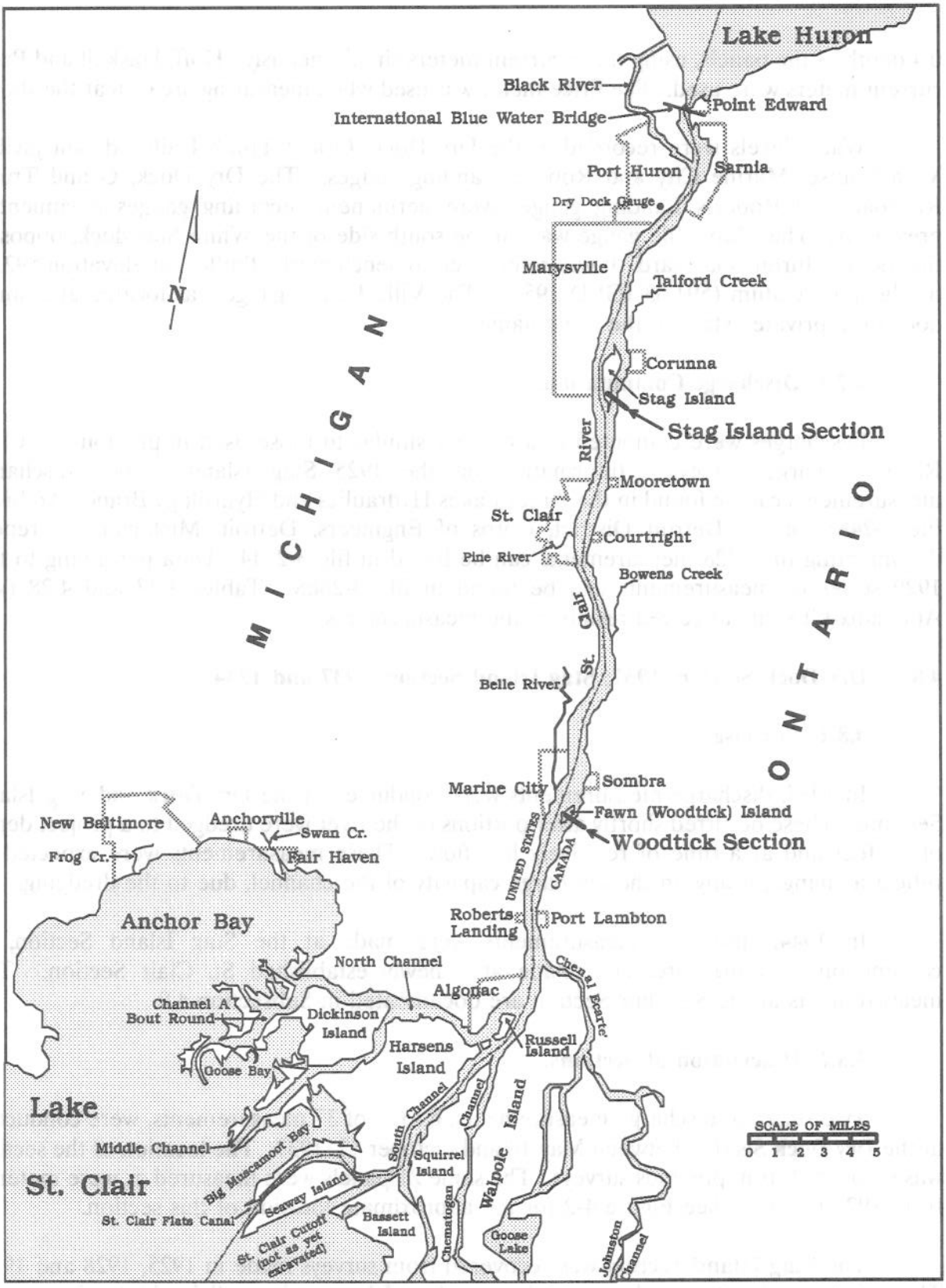

Figure 4-3

St. Clair River, 1925-1929 Section Locations

0.4 depth of the panels, using three current meters simultaneously. Hoff, Haskell and Price current meters were used. The Price meter was used when measuring areas near the shore.

Water levels were recorded at the Dry Dock, Grand Trunk Railroad, Marysville, Villa Louise, Marine City and Roberts Landing gauges. The Dry Dock, Grand Trunk Railroad and Roberts Landing gauges were permanent recording gauges documented previously. The Marysville gauge was on the south side of the White Star dock, opposite the foot of Huron Boulevard. It was referenced to bench mark "Trolley" at elevation 592.74 on the 1903 Datum (591.03 IGLD 1955). The Villa Louise gauge was located at a small dock on a private estate of the same name.

4.7.4 Discharge Computation.

Discharges were computed in a manner similar to those used in previous St. Clair River discharge surveys. Information on the 1925 Stag Island Section discharge measurements can be found in the Great Lakes Hydraulics and Hydrology Branch Archives file 3-2481, of the Detroit District, Corps of Engineers, Detroit, Michigan. A report documenting the 1928 measurements can be found in file 3-2544. Data pertaining to the 1929 series of measurements can be found in file 3-2668. Tables 4.27 and 4.28 (see Appendix C) summarize the results of the measurements.

4.8 Dry Dock Section, 1937; Stag Island Section, 1937 and 1944.

4.8.1 Purpose.

In 1937, discharge measurements were conducted at the Dry Dock and Stag Island Sections. These occurred shortly after portions of the river were dredged to a project depth of 25 feet and at a time of relatively low flow. These measurements were expected to reflect a change, if any, in the discharge capacity of the channel, due to the dredging.

In 1944, discharge measurements were made at the Stag Island Section, in conjunction with measurements made at a newly established St. Clair Section. The measurements at the St. Clair Section are documented in Subsection 4.9.

4.8.2 Description of Sections.

Two series of discharge measurements, a total of 37 measurements, were conducted at the **Dry Dock Section** between May 18 and October 12, 1937. The location of the section was recovered from previous surveys. The same 21 panels were measured as were metered from 1924 to 1930. See Figure 4-2 for the approximate location of this section.

The **Stag Island Section** was recovered from surveys made in 1925, 1928 and 1929. The section was located on the channel east of Stag Island and was divided into nine panels. Ten measurements of flow past the section were made between October 14 and 19, 1937.

Eleven measurements were made at this section, during the period July 17-20, 1944. See Figure 4-3 for the approximate location of this section.

4.8.3 Measurement Techniques.

Both sections were sounded prior to making discharge measurements. Soundings at the Stag Island Section in 1937 indicated no change in area since the 1929 measurements. Because the section remained unchanged, vertical velocity measurements were considered unnecessary in 1937, and none were made. Soundings at Stag Island in 1944 indicated that a small amount of dredging had occurred in panels 7 and 8, since 1937. However, it was not considered serious enough to warrant new (1944) vertical velocity measurements.

At the Dry Dock Section, vertical velocity measurements, to determine vertical velocity coefficients, were taken throughout the 1937 season. One index meter was kept at the 0.5 depth and two other meters measured velocities at the surface, the 0.1, 0.3, 0.7, 0.9 depths and near the bottom of each panel. The various depth velocities were tabulated as a percent of the mean 0.5 velocity.

Discharge measurements at both sections, during both years, were made using three meters suspended simultaneously at the 0.5 depth.

Water levels at Harbor Beach, Fort Gratiot, Grand Trunk Railroad, Dry Dock, Roberts Landing and Grosse Pointe Yacht Club gauges were correlated to the discharge measurements made at the sections. Listed below are the controlling bench marks for the water level recording gauges referenced and the elevations of these bench marks.

Water Level Gauge	Controlling Bench Mark	Bench Mark Elevations (feet) 1935 Datum
Fort Gratiot	Retaining Wall	590.17
Grand Trunk RR.	GTR	587.91
Dry Dock	Grate Bar (1926)	597.24
Roberts Landing	Hick (1936)	583.39

4.8.4 Discharge Computation.

Vertical velocity coefficients for the Dry Dock Section did not change significantly from the 1925-1928 measurements; consequently, the latter were used for all panels, except panels 1, 2 and 21, for which more data were recovered. New curves and coefficients for these panels (1, 2 and 21) were constructed from the 1937 data and used in determining discharges for these end panels. Transverse coefficients did change slightly in the area of dredging and these newer coefficients were used in the discharge reduction computations.

Vertical velocity coefficients determined in 1929 for the Stag Island Section were used in both the 1937 and 1944 discharge computations. Transverse velocity coefficients and panel areas were determined from the 1937 and 1944 measurements.

The discharge was determined by applying both the vertical and transverse coefficients for each panel to the 0.5 depth velocity and multiplying the panel area by the adjusted velocity.

Reports documenting the 1937 series of measurements can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, files 3-2551 and 3-2961, of the Detroit District, Corps of Engineers, Detroit, Michigan. The 1944 measurements at the Stag Island Section are documented in files 3-3038 and 3-3084. Tables 4.29 to 4.32 (see Appendix C) summarize these measurements.

4.9 St. Clair Section, 1944-1950.

4.9.1 Purpose.

The St. Clair Section was established to replace the Dry Dock Section. A certain amount of dredging had occurred between 1932 and 1936, and with the possibility of further dredging, which would affect the calibration of the section, it was thought best to establish a new section. With this view in mind and the desire for selecting the best possible site available, the cross sections of the entire river were examined and a site was selected, which had continuity of flow and ample water for navigation.

Discharge measurements were made at the St. Clair Section, during six different periods between 1944 and 1950. These measurements were made to provide data for a study that was being made of the hydraulics of the St. Clair River, after the completion, in 1936, of a project to provide 24 foot navigation depths. All measurements were carried out by personnel from the U.S. Lake Survey District, Corps of Engineers.

4.9.2 Description of Section.

The **St. Clair Section** was established in 1944 and recovered in 1947, 1949 and 1950. The section, located 3.2 miles below the Pine River at St. Clair, Michigan, extended from the U.S. to the Canadian shore and was divided into 11 panels.

Below is a listing of survey dates documented in this section and the number of measurements made during each period.

Dates of Survey	Number of Measurements
June 8 to July 11, 1944	24
September 22 to October 31, 1944	23
June 19 to July 16, 1947	22
October 21 to November 5, 1947	23
April 11 to April 21, 1949	16
October 3 to October 12, 1949	19
July 6 to July 19, 1950	20
September 18 to September 29, 1950	20

The location of this discharge measurement section is shown on Figure 4-4.

4.9.3 Measurement Techniques.

Discharge measurements were made in both the summer and fall of each year. Soundings of the section were made prior to each discharge measurement period. All velocity measurements were conducted in a manner similar to that used for the 1927-1928 measurements made at the Dry Dock Section.

A thorough vertical velocity survey was made of the section in the Spring of 1944. Vertical velocity measurements were again made at the two end panels in 1947. Discharge measurements taken at the section were made with three Haskell current meters suspended simultaneously at the 0.4 depth.

Water level elevations were recorded at the Fort Gratiot, Grand Trunk Railroad, Dry Dock, Marysville, St. Clair, St. Clair Section, Marine City and Roberts Landing gauges for the various discharge measurement surveys described in this section. The Fort Gratiot gauge was located at the Port Huron Coast Guard Station near the Fort Gratiot Lighthouse and was a Stevens automatic gauge. The Grand Trunk Railroad gauge was a self-registering gauge installed at the Grand Trunk Railroad ferry slip, about 3,600 feet below the Fort Gratiot Lighthouse. The Dry Dock gauge was located in front of a house at 3300 Military Street, Port Huron, Michigan, and was a Haskell automatic gauge. The Marysville gauge was a temporary recording gauge placed for the 1947 survey on a dock at the foot of Huron Boulevard in Marysville, Michigan. The St. Clair gauge was located at the City of St. Clair, Michigan, approximately 160 feet upstream from the upstream bank of the Pine River, and was a Bristol 928 automatic gauge. The St. Clair Section gauge, a temporary gauge, was located on the U.S. side of the St. Clair River, approximately 100 feet downstream of the hydraulic section line. The Roberts Landing gauge was located on the upstream side of the ferry dock at Roberts Landing and was a Stevens automatic gauge.

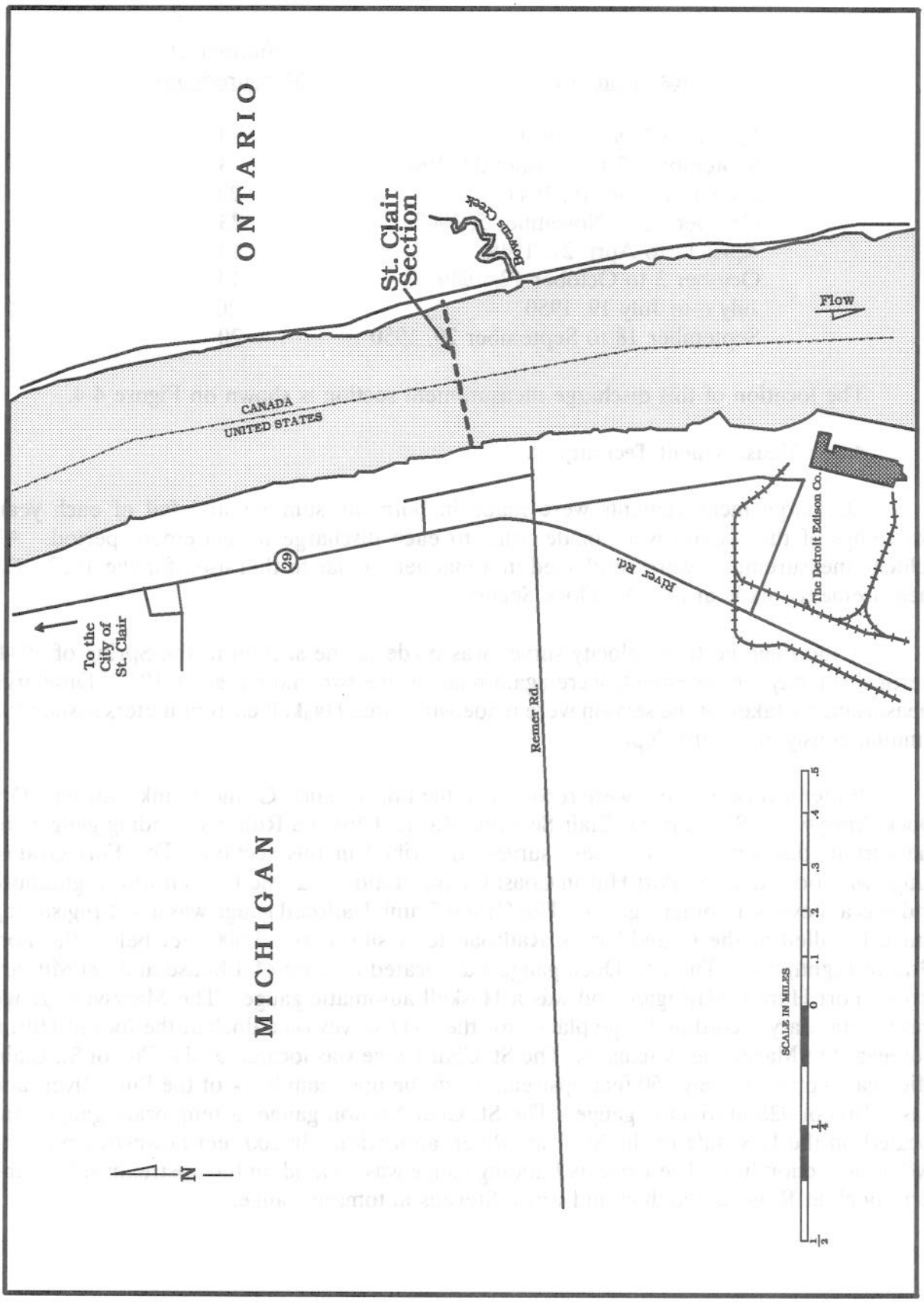

Figure 4-4

St. Clair River, 1944-1950 St. Clair Section Location

The following is a list of the controlling bench marks for the water level gauges referenced and their bench mark elevations.

Water Level Gauge	Controlling Bench Mark	Bench Mark Elevations (feet) 1949 Adjustment of 1935 Datum
Fort Gratiot	Retaining Wall	590.14
Grand Trunk RR.	GTR	587.87
Dry Dock	Grate Bar	596.80
Marysville	G-21	587.81
St. Clair	M	588.75
Section	Russ	586.68
Marine City	C-41	588.85
Roberts Landing	Landing	582.66

4.9.4 Discharge Computation.

Transverse velocity coefficients were determined for each series of measurements and were used to reduce that particular set of measurements. Vertical velocity coefficients were computed for all the panels in 1944. In 1947, vertical velocity coefficients were recomputed for the two end panels using information gathered during that survey.

The data and reports for the measurements described in this section can be found in the Great Lakes Hydraulics and Hydrology Branch Archives of the Detroit District, Corps of Engineers, Detroit, Michigan. File 3-3164 contains the 1944 data. The data for the 1947 measurements are in file 3-3163. The spring 1949 measurements are documented in file 3-3165 and the fall measurements are in file 3-3144. The measurements made in 1950 are documented in file 3-3295. Tables 4.33 to 4.39 (see Appendix C) summarize the resulting discharges.

4.10 Dry Dock, Stag Island, North Channel and St. Clair Sections, 1947.

4.10.1 Purpose.

Hydraulic discharge measurements were made at the Dry Dock, Stag Island, North Channel and St. Clair Sections, during the Summer and Fall of 1947. The measurements made at the St. Clair Section are documented in Subsection 4.9. These surveys were carried out by the U.S. Lake Survey District, Corps of Engineers.

4.10.2 Description of Sections.

The **Dry Dock Section** was recovered from previous surveys. It was located about 2-1/2 miles below the mouth of the Black River, at 3300 Military Street, Port Huron,

Michigan. The section extended from the U.S. to the Canadian shore and was divided into 21 panels. A total of 23 discharge measurements were made for this survey, between August 5 and 22, 1947. The approximate location of this discharge measurement section is shown on Figure 4-2.

The **Stag Island Section** was established in May 1925 and recovered for this survey. The section was located near the lower end of Stag Island and extended from the island to the Canadian shore, a distance of about 1,110 feet. The section was divided into nine panels. A series of 12 measurements were made between July 21 and 28, 1947. The approximate location of this discharge measurement section is shown on Figure 4-3.

The **North Channel Section** was established for this survey. It was located about six miles below Algonac, Michigan; approximately 1,000 feet below the old Salt Block Section (1910). The section was divided into six panels. Between October 9 and 17, 1947, a series of 13 discharge measurements were made at this section. The approximate location of this discharge measurement section is shown on Figure 4-7.

4.10.3 Measurement Techniques.

Each section was sounded prior to the taking of discharge measurements. Soundings indicated that the Stag Island Section, in the vicinity of panel 8, had been dredged since the last survey in 1925.

Vertical velocity measurements were made at all panels of the North Channel Section and at panel 8 of the Stag Island Section and panels 2 and 21 of the Dry Dock Section. Transverse velocity observations were made at all sections.

All velocity measurements were made by suspending three Haskell meters simultaneously at the 0.4 panel depth.

Water level elevations were recorded at the Fort Gratiot, Dry Dock, St. Clair, Grand Trunk Railroad and Roberts Landing gauges, during these surveys. The Fort Gratiot gauge was located at the Port Huron Coast Guard Station, near the Fort Gratiot Lighthouse. A Stevens automatic gauge was used. Grand Trunk Railroad gauge, a self-registering gauge, was installed at the Grand Trunk Railroad ferry slip, about 3,600 feet below the Fort Gratiot Lighthouse. The Dry Dock gauge, a Haskell automatic gauge, was located at 3300 Military Street, Port Huron, Michigan. The St. Clair gauge, a Bristol 928 automatic gauge, was located approximately 160 feet upstream of the Pine River. The Roberts Landing gauge, a Stevens automatic gauge, was located on the upstream side of the ferry dock at Roberts Landing.

Listed below are the controlling bench marks for the water level gauges referenced and their bench mark elevations.

Water Level Gauge	Controlling Bench Mark	Bench Mark Elevations (feet) 1949 Adjustment of 1935 Datum
Fort Gratiot	Retaining Wall	590.14
Grand Trunk RR.	GTR	587.87
Dry Dock	Grate Bar	596.80
St. Clair	M	588.75
Roberts Landing	Landing	582.66

4.10.4 Discharge Computation.

Transverse velocity coefficients were determined at each section from transverse curves developed, based on the velocity measurements made in 1947. The vertical velocity coefficients for the Dry Dock Section were determined from 1925 and 1928 observations, except for panels 2 and 21, which were determined from 1947 measurements. Vertical velocity coefficients for the Stag Island Section were those determined in 1929, except for panel 8, which was redetermined with data from this survey. Vertical velocity coefficients for the North Channel Section were determined from this survey.

A combined coefficient for each panel of a section was determined by multiplying the transverse, vertical and directional coefficients. The mean velocity through the panel was determined by multiplying the measured velocity by the combined coefficient. The mean velocity in the panel was multiplied by the panel area to obtain the panel discharge. The total discharge through a section was obtained by summing each panel discharge.

The discharges determined from these surveys are listed in Tables 4.40 to 4.42 (see Appendix C). A report on these measurements can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file 3-3118, of the Detroit District, Corps of Engineers, Detroit, Michigan. Additional information on the Dry Dock and Stag Island Sections can be found in files 3-3125 and 3-3126, respectively.

4.11 St. Clair Section, 1952.

4.11.1 Purpose.

The purpose of the 1952 St. Clair Section discharge measurements was to determine the total flow in the St. Clair River at a time of extreme high water levels on Lake Huron. All field work was carried out by personnel from the Lake Survey District, Corps of Engineers.

4.11.2 Description of Section.

The **St. Clair Section** was originally established in 1944. The section was located

about 3.2 miles south of Pine River, in the City of St. Clair, Michigan. There were eleven panels in the section and the section extended 1,590 feet across the St. Clair River from the U.S. to the Canadian shore. A total of 13 discharge measurements were made between August 11 and 18, 1952.

The location of this discharge measurement section is shown on Figure 4-4.

4.11.3 Measurement Techniques.

There were no soundings made for the 1952 St. Clair Section survey. The mean area for the entire section was determined using all of the section's previous soundings. Discharge measurements were made only at the metering station of panel 5 and only at the index point (0.4 depth). For each discharge measurement, three Haskell current meters were lowered simultaneously to the 0.4 depth, and 12 to 40 two-minute observations of velocity were made.

Water surface elevations were recorded at the Fort Gratiot, St. Clair, St. Clair Section, Roberts Landing and Algonac gauges. Listed below are the controlling bench marks for these gauges and their elevations.

Water Level Gauge	Controlling Bench Mark	Bench Mark Elevations (feet) 1949 Adjustment of 1935 Datum
Harbor Beach	Huron	583.64
Fort Gratiot	Retaining Wall	590.14
Dry Dock	Grate Bar	596.80
St. Clair	Kemp	588.96
Section	Russ	586.68
Roberts Landing	Landing	582.66
Grosse Pointe Yacht Club	Yacht Club	579.84
Algonac	Zieske	582.93

4.11.4 Discharge Computation.

A combined vertical, transverse and direction coefficient was computed and was referred to as the section coefficient. The section coefficient was established using the observed discharges and index point velocities at panel 5 made in 1947, 1949 and 1950.

For each discharge measurement, each individual velocity observation was multiplied by the section coefficient to determine flow values. Then each of the individual flows, computed from observations from a particular meter, were averaged. The average flows for each of the three meters used in the particular measurements were then averaged to get the final value for that discharge measurement.

The summary of discharges determined from this survey are listed in Table 4.43 (see Appendix C). The data for the 1952 measurements are documented in the Great Lakes Hydraulics and Hydrology Branch Archives, file 3-3300, of the Detroit District, Corps of Engineers, Detroit, Michigan.

4.12 St. Clair Section, 1953

4.12.1 Purpose.

This series of hydraulic discharge measurements were conducted to 1) evaluate the regular U.S. Lake Survey District method of measuring discharge under winter conditions; and 2) to determine whether the flow past a calibrated section could be ascertained from velocities observed at one to three index points, instead of the many index points which were used to calibrate the section.

4.12.2 Description of Section.

The **St. Clair Section,** recovered from previous surveys, was located about 3.2 miles south of Pine River, in the City of St. Clair, Michigan. The section line extended from the U.S. to the Canadian shore, approximately 1,590 feet. For this survey, the section was again divided into 11 panels. There were 17 discharge measurements made between February 7 and March 5, 1953. The location of this discharge measurement section is shown on Figure 4-4.

4.12.3 Measurement Techniques.

There were no soundings made during the 1953 St. Clair Section survey. Mean areas were determined from previous soundings. The velocity observations, needed to compute discharges, were made using the following three different methods:

1) The regular U.S. Lake Survey District method was followed, in which the velocities were observed at the index point of each of the 11 panels. The panel index point was the center point of the panel at the 0.4 depth.

2) A method where the section was divided into three panels; designated A, B and C. The index point of panel 3 was used as the index point for Section A, the index point of panel 5 for Section B and the index point of panel 7 for Section C.

3) The third method involved observing the velocity at the index point of panel 5 only.

For any particular measurement, three Haskell current meters were suspended at the 0.4 depth of the panel being measured.

When all 11 panels were metered, only one velocity observation was made at each panel index point for that measurement. For measurements, where only one or three panels were metered, several velocity observations were made at the panel index points.

Water levels were recorded at the gauges listed below. The bench marks to which these gauges were referenced are also listed.

Water Level Gauge	Controlling Bench Mark	Bench Mark Elevations (feet) 1949 Adjustment of 1935 Datum
Fort Gratiot	Retaining Wall	590.14
St. Clair	Kemp	588.95
Roberts Landing	Landing	582.66
Dry Dock	Grate Bar	596.80
Section	Russ	586.68
Algonac	Rim	580.15

4.12.4 Discharge Computation.

In analyzing the data obtained, the panel velocities observed during the crossings, which encompassed all 11 panel points, were averaged and used to draw the transverse velocity curve. Depending upon the number of panels in the discharge measurement (one, three or eleven), different transverse velocity coefficients were determined. The area under the transverse velocity curve was determined for each panel of each panel configuration. The transverse velocity coefficient for the panel was determined by dividing this area by the panel width and then by the average velocity at the index point of the panel.

The vertical velocity and directional coefficients for the 11-panel configuration were the same as those developed for the measurements made at this section in 1944. Using these coefficients, corresponding coefficients were determined for the three-panel and the one-panel configurations. Combined vertical-transverse-directional coefficients were determined for each panel of each of the three configurations.

For all measurements, the observed velocities were multiplied by the appropriate combined coefficient for that panel and panel configuration to get the mean panel or section velocity. The product of the mean panel velocity and the panel area was the panel discharge. The panel discharges for a particular measurement were summed to get the total discharge.

Table 4.44 (see Appendix C) summarizes the discharge measurements made for this survey. The results of these 1953 St. Clair Section discharge measurements are documented in the Great Lakes Hydraulics and Hydrology Branch Archives, File 3-3349, of the Detroit District, Corps of Engineers, Detroit, Michigan.

4.13 Blue Water Section, 1954.

4.13.1 Purpose.

The purpose of this survey was to test an alternate method of measuring the winter discharge of the St. Clair River. In the previous winter, discharge measurements made from a catamaran were hampered by ice floes. It was felt that this hazard could be avoided if measurements could be made from the Blue Water Bridge. All work for this survey was performed by the U.S. Lake Survey District, Corps of Engineers.

4.13.2 Description of Section.

The **Blue Water Section** was established in November 1953, just below the Blue Water Bridge, between Port Huron, Michigan, and Point Edward (Sarnia), Ontario. Measurements were conducted from the Blue Water Bridge. The section was divided into eight panels, averaging about 100 feet in width. Between January 16 and March 15, 1954, a total of 32 discharge measurements were made.

The location of this discharge measurement section is shown on Figure 4-5.

4.13.3 Measurement Techniques.

All measurements were made from the downstream side of the Blue Water Bridge. Wet-line and air-line corrections were made to determine the true depths during soundings, and to place meters at their proper depths for discharge measurements. Two sets of soundings were made at the section.

Because only one meter could be lowered at a time, separate vertical velocity observations (observations at each tenth of the depth) were not made. Instead, for each discharge measurement, several two-minute velocity observations were made at the 0.2 and 0.8 depths of each panel and the mean of these was taken as the average velocity in the vertical.

A direction of flow survey was conducted using a number of partially submerged floats.

Water surface elevations were recorded at the Fort Gratiot, Dry Dock and Roberts Landing gauges, as well as at a staff gauge located on the line of the section. The section gauge was controlled by level connections to bench marks "Gorge" (elevation 585.27 feet, 1935 Datum) and "IBM56" (elevation 589.58 feet, 1935 Datum; 587.80 feet, IGLD 1955.)

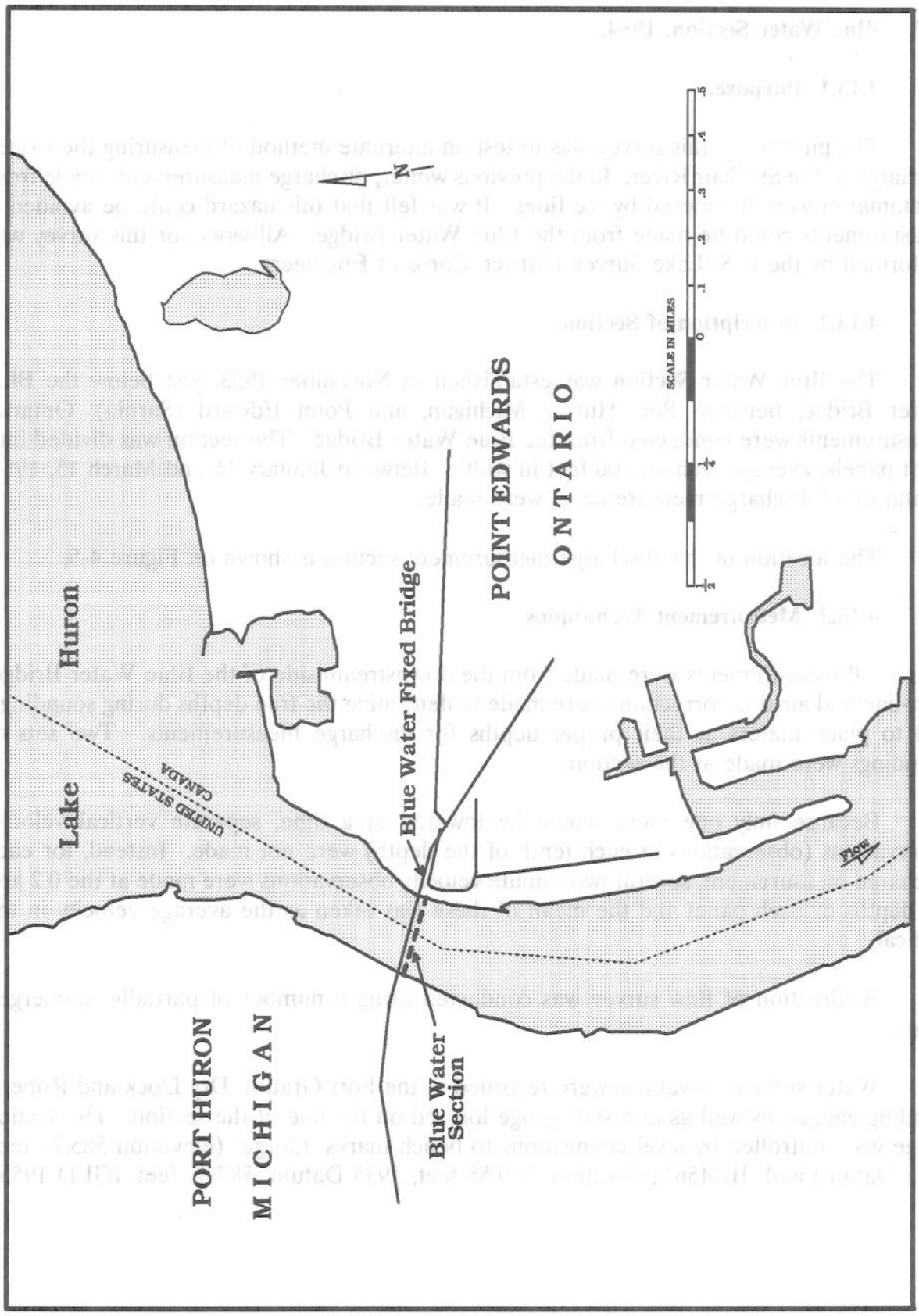

Figure 4-5

St. Clair River, 1954 Blue Water Section Location

4.13.4 Discharge Computation.

The discharge through the section for a particular measurement was determined by adding the individual panel discharges. The panel discharges were obtained by multiplying the mean panel velocity observed during that measurement by a combined coefficient for that panel.

The combined coefficient incorporated a directional coefficient, determined from the direction of flow measurements, and a transverse coefficient, derived from the velocity measurements. The mean of all the velocities measured in a panel were plotted at the panel point. The area under the resulting curve was divided by the panel width. This, in turn, was divided by the mean observed velocity in the panel. The result was the transverse coefficient.

The results of the discharge measurements made for this survey are given in Table 4.45 (see Appendix C). A copy of the report fully documenting this survey can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file 3-3685, of the Detroit District, Corps of Engineers, Detroit, Michigan.

4.14 Bay Point Section, 1959-1968.

4.14.1 Purpose.

The Bay Point Section was established to monitor the St. Clair River outflow regimen as dredging of the 27-foot deep navigation channel progressed, and after it was completed. The information gathered from these surveys was used in the derivation of stage-discharge relationships.

All of the surveys made at the Bay Point Section and documented in this section were conducted by the U.S. Lake Survey District, Corps of Engineers.

4.14.2 Description of Section.

The Bay Point Section was established in 1959 and recovered for subsequent surveys. It was located north of the Black River, near the foot of Rawlins Street in Port Huron, Michigan. It extended across the St. Clair River to the southerly end of the Bay Point Peninsula in Ontario, Canada.

For all surveys between 1959 and 1966, the section was divided into eight panels, each 160 feet wide, except panel 8, which was 184.5 feet wide. For the measurements made in 1968, the section was broken down into 17 panels, ranging from 53 to 92 feet wide.

The following listing is a summary of the number of measurements that were made during the surveys discussed in this subsection, and when they were made.

Date of Survey	Number of Measurements
July 28 - August 11, 1959	26
October 29 - November 12, 1959	35
April 12-28, 1960	26
May 7-22, 1962	27
August 29 - September 15, 1962	42
September 27 - October 16, 1963	30
August 3-22, 1964	42
November 2-20, 1964	27
October 21 - November 15, 1966	29
June 19 - July 10, 1968	30

The approximate location of this discharge measurement section is shown on Figure 4-6.

4.14.3 Measurement Techniques.

The section was sounded three times prior to and during the 1959 series of measurements. The mean of these soundings were used to reduce the discharge measurements made in 1959 and 1960. During subsequent surveys, the section was sounded prior to each series of measurements.

For the series of measurements made in 1959 and 1966, velocity measurements were made at each panel point, by suspending three current meters, concurrently, at the 0.2, 0.4 and 0.8 depths of the panel and taking a four-minute reading. The observations made in 1963 measured velocities at the 0.2 and 0.8 depths of the panels. The 1960, 1962, and 1964 series of discharge measurements were made by taking four-minute readings at the 0.4 depth only, using three meters suspended concurrently at the panel point.

In 1968, velocity measurements were made at each tenth of depth, to determine the discharge through the panel. Eleven Price current meters were suspended at the panel point simultaneously. One meter was placed at each of the tenth depths. Meters were also placed one foot and one half foot above the bottom. These last two measurements in the vertical were not used for discharge computations, but were made as a part of a study of the vertical velocity curve.

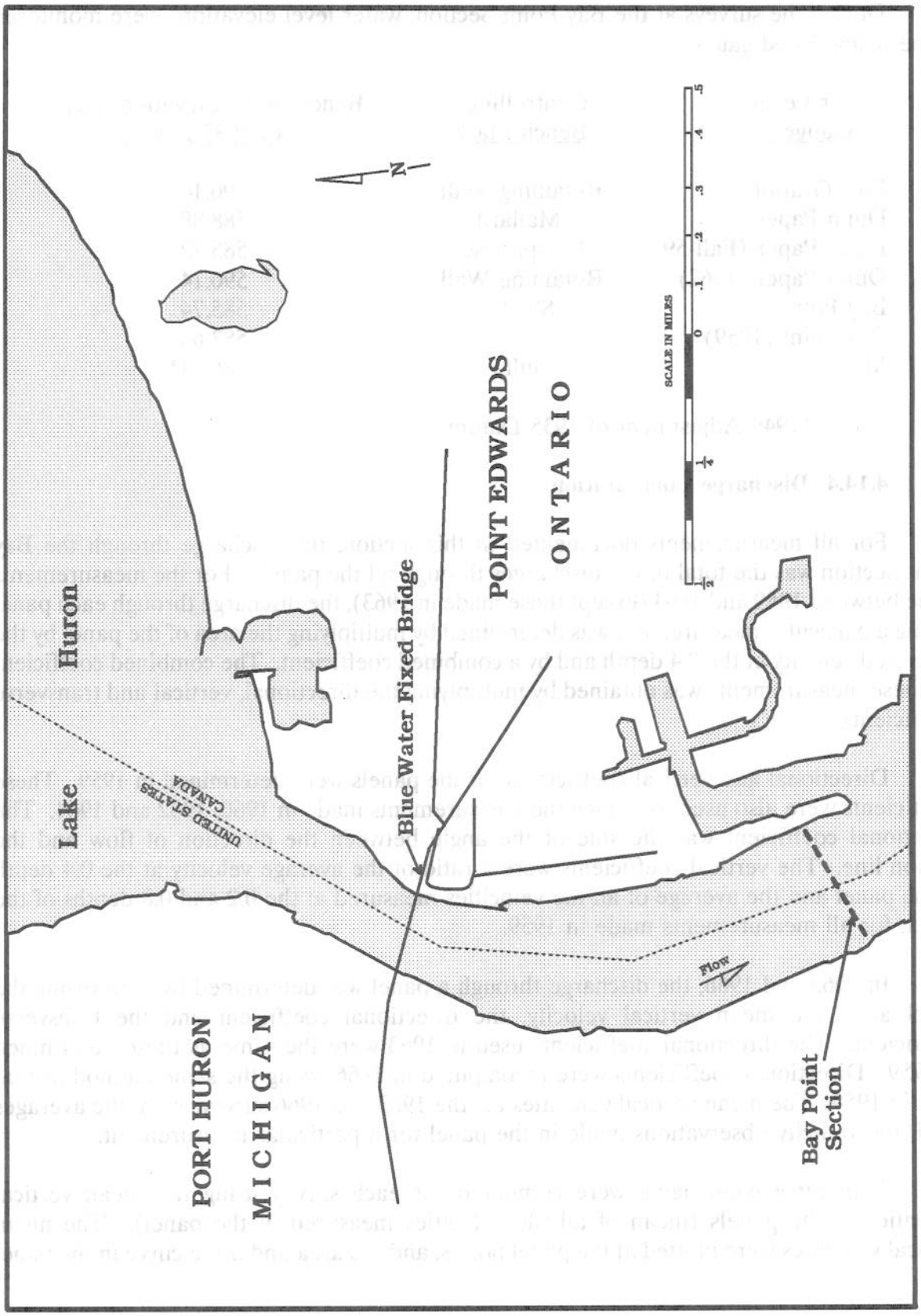

Figure 4-6

St. Clair River, 1959-1968 Bay Point Section Location

During the surveys at the Bay Point Section, water level elevations were monitored at the below listed gauges:

Water Level Gauge	Controlling Bench Mark	Bench Mark Elevations (feet) of 1935 Datum
Fort Gratiot	Retaining Wall	590.14
Dunn Paper	Mallard	588.88
Dunn Paper (Fall-59)	Pumphouse	585.72
Dunn Paper (1962)	Retaining Wall	590.14
Bay Point	Shed	585.74
Bay Point (1959)	C	583.68
MBR	Gulf	586.74*

*1949 Adjustment of 1935 Datum.

4.14.4 Discharge Computation.

For all measurements documented in this section, the discharge through the Bay Point Section was the total of the discharges through all the panels. For the measurements made between 1959 and 1964 (except those made in 1963), the discharge through each panel during a particular measurement was determined by multiplying the area of the panel by the measured velocity at the 0.4 depth and by a combined coefficient. The combined coefficient for these measurements was obtained by multiplying the directional, vertical and transverse coefficients.

Directional and vertical coefficients for the panels were determined in 1959. These coefficients were also used to reduce the measurements made in 1960, 1962 and 1964. The directional coefficient was the sine of the angle between the direction of flow and the section line. The vertical coefficients were a ratio of the average velocity at the 0.4 depth of the panel and the average of all the velocities measured at the 0.2 and 0.8 depths of the panel, for all measurements made in 1959.

In 1963 and 1966, the discharge through a panel was determined by multiplying the panel area, the mean vertical velocity, the directional coefficient and the transverse coefficient. The directional coefficients used in 1963 were the same as those determined in 1959. Directional coefficients were recomputed in 1966, using the same method as that used in 1959. The mean vertical velocities for the 1963 and 1966 surveys were the averages of all the velocity observations made in the panel for a particular measurement.

Transverse coefficients were computed for each survey using the mean vertical velocities in the panels (mean of all the velocities measured in the panel). The mean vertical velocities were plotted at the panel points, and the area under the curve in the panel

was determined. This area was divided by the panel width and this, in turn, was divided by the mean vertical velocity in the panel, to obtain the transverse coefficient for the panel.

The 1968 measurements at the Bay Point Section were reduced using a computer program written by the Corps of Engineers. This program is documented in Appendix A.

In 1973, the discharges for the 1960-1966 measurements were recomputed using a modified version of the above mentioned program. The program inputs were the panel areas, the vertical and directional coefficients for each panel, the velocity observations for each panel and each measurement, and the water level at the section gauge. The velocity in the vertical of a panel was the average of all velocity observations for the measurement multiplied by the vertical coefficient. The transverse velocity was computed in the same manner as that used in 1968.

Tables 4.46 through 4.55 (see Appendix C) summarize the discharge measurements made at the Bay Point Section during the period 1959 to 1968. Reports and data from these surveys are kept in the Great Lakes Hydraulics and Hydrology Branch Archives of the Detroit District, Corps of Engineers, Detroit, Michigan. The years of the surveys and their archive file numbers are listed below.

Survey	Archive File
1959	3-3878 A and B
1960	3-3967
1962	3-3986
1963-64	3-4021, 3-4022, 3-4145
1966	3-4358
1968	72-1

4.15 Lower St. Clair River: Roberts Landing, North Channel, Middle Channel, Chenal Ecarté, South Channel, St. Clair Cutoff, Southeast Bend, Bassett Channel and Chematogan Channel Sections, 1963 and 1968.

4.15.1 Purpose.

During the period July through September 1963, eight hydraulic sections were established to determine the distribution of flow through the various channels of the lower St. Clair River. The channels in which hydraulic sections were established are as follows: 1) North Channel, 2) Middle Channel, 3) South Channel, 4) Chenal Ecarté, 5) Southeast Bend, 6) St. Clair Cutoff, 7) Bassett Channel and 8) Chematogan Channel. The primary flow distribution of one hundred per cent of total river flow was considered to be carried through channels numbered one through four. The channels numbered five through eight represent the distribution of flow carried by the South Channel. During the period July through August 1968, several series of hydraulic discharge measurements were made for the

same reason as those in 1963. Measurements were also made at the Roberts Landing Section, to measure total river flow.

Measurements were made as a joint effort between the U.S. Lake Survey District, Corps of Engineers, and the Water Survey of Canada. The data were reduced by personnel from the Corps of Engineers.

4.15.2 Description of Sections.

The **Roberts Landing Section** measured the total river flow. The section was established above the confluence of the Chenal Ecarté and extended from the U.S. mainland, near Roberts Landing Michigan, to the Canadian shore, near Port Lambton, Ontario. For the 1968 survey, the section consisted of 20 panels, not including 111 feet of dead water at the east end of the section. A total of 37 discharge measurements were made, during the period July 17 and August 16, 1968.

The **North Channel Section** was located in the lower portion of the North Channel and extended from the U.S. mainland to Dickinson Island. For the 1963 survey, the section was divided into six panels. Each panel was 160 feet in width, except panel six, which was 200 feet in width. Thirteen discharge measurements were made at this section, between July 8 and 17, 1963. For the 1968 survey, the section was divided into seven panels. Fifteen discharge measurements were made in this section, between July 17 and July 23, 1968.

The **Middle Channel Section** was established at the head of this channel and extended from Dickinson Island to Harsens Island. For the 1963 survey, the section was divided into four panels. Each panel was 150 feet in width except panel four, which was 250 feet in width. Thirty-five discharge measurements were made at this section between July 24 and July 30, 1963. For the 1968 survey, the section was divided into five panels. Sixteen discharge measurements were made between July 17 and July 23, 1968.

The **Chenal Ecarté Section** was located approximately 4,500 feet downstream from the head of this channel and extended from the Canadian mainland to Walpole Island. For the 1963 survey, the section was divided into three panels, 110 feet, 110 feet and 120 feet in width, respectively. Twenty-eight discharge measurements were made at this section, between August 16 and 20, 1963. For the 1968 survey, the section was divided into six panels and 18 discharge measurements were made between August 12 and 16, 1968.

The **South Channel Section** was located at the head of the South Channel and extended from Walpole Island to Russell Island. For the 1963 survey, the section was divided into seven panels. The interior panels were each 150 feet in width. Panels one and seven were 170 feet and 250 feet in width, respectively. Twenty-three discharge measurements were made at this section, between August 5 and 15, 1963. For the 1968 survey, the section was divided into seven panels, which did not include the 120 to 160 feet

of dead water on either end of the section. A series of ten discharge measurements was completed between August 12 and August 16, 1968.

The **St. Clair Cutoff Section** was established across the head of the St. Clair Cutoff Canal, from Seaway Island to Bassett Island. For the 1963 survey, the section was divided into five panels. Panels one through four were each 200 feet in width and panel five was 230 feet in width. Eighteen discharge measurements were made between August 27 and September 16, 1963. For the 1968 survey, the section was divided into nine panels, which did not include a section of dead water near the south shore. Ten measurements were made at this section, from July 26 to August 3, 1968.

The **Southeast Bend Section** was located on the southeast bend of the South Channel and extended from Harsens Island to Seaway Island. For the 1963 survey, the section was divided into five panels. The interior panels were each 180 feet in width. Panels one and five were 140 feet and 150 feet in width, respectively. Seventeen discharge measurements were made at this section, between August 28 and September 18, 1963. For the 1968 surveys, the section was divided into ten panels. Ten discharge measurements were made between July 26 and August 3, 1968.

The **Bassett Section** was located about 3,000 feet downstream from the head of Bassett Channel, which runs primarily through marshlands. The section stretched from Bassett Island to Squirrel Island. For the 1963 survey, the section was divided into three panels of 100 feet each. Twelve discharge measurements were made between September 17 and September 21, 1963. For the 1968 survey, the section consisted of six panels and was bordered on either side by marsh. Ten discharge measurements were made at this section, during the period August 6 through August 9, 1968.

The last hydraulic section metered was the **Chematogan Channel Section,** located near the head of the Chematogan Channel. Forty discharge measurements were made at the center of this section, between August 6 and August 10, 1968.

The approximate locations of these discharge measurement sections are shown on Figure 4.7.

4.15.3 Measurement Techniques.

In 1963, each section was sounded by lead line with the positioning determined by transit intersection. Soundings were plotted to develop bottom profiles for each section. The direction of flow for the various sections was determined by tracking weighted floats past the section line.

Observations were made simultaneously at the 0.2 and 0.8 depths in each section, during the discharge measurements. The mean of the 0.2 and 0.8 depth velocity represents

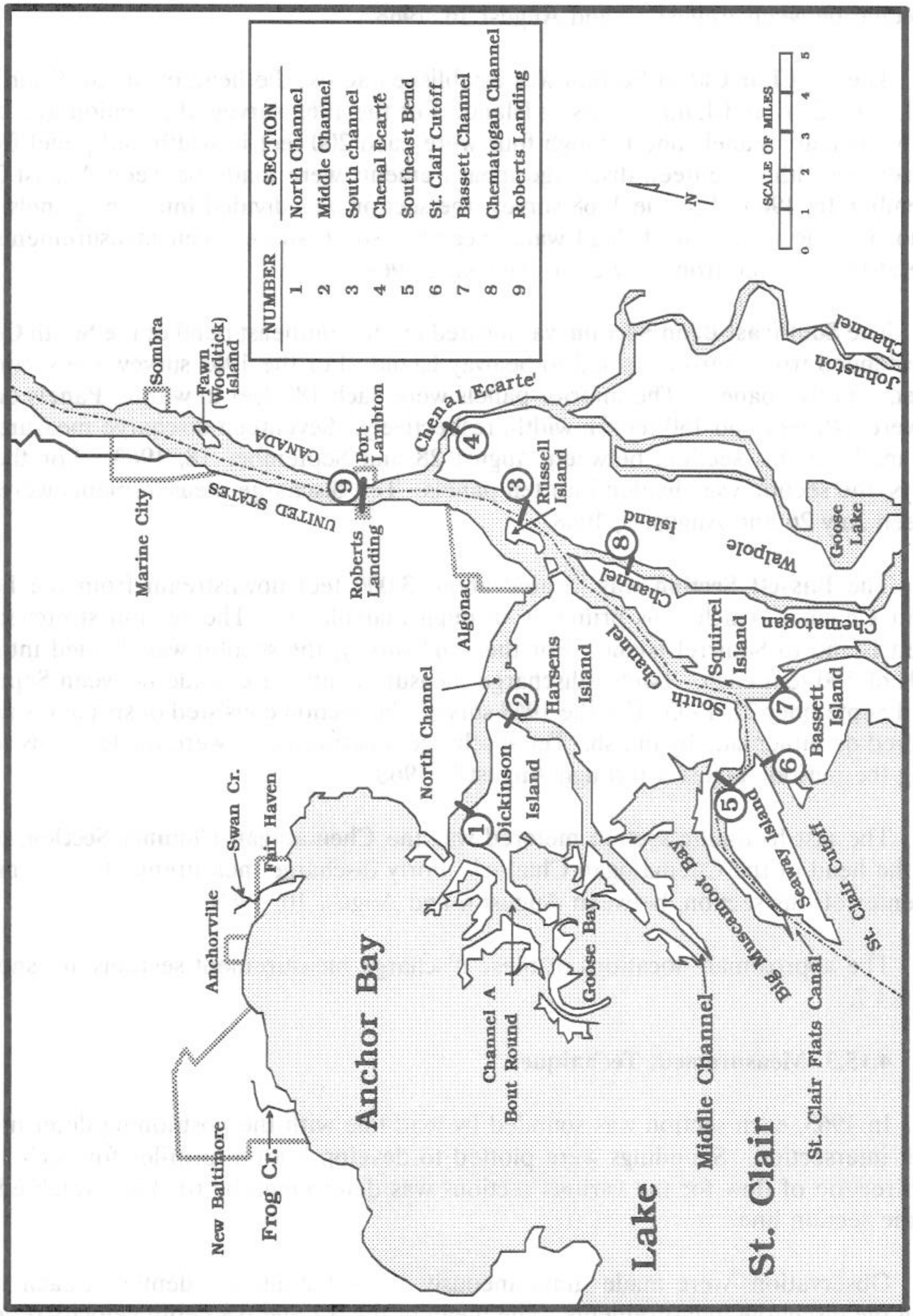

Figure 4-7

Lower St. Clair River, 1963 & 1968 Section Locations

the mean velocity in the vertical. Five Price current meters were used for the various discharge measurements.

At the Chematogan Channel Section, horizontal control was established by chaining, from water's edge to water's edge, along the upstream edge of a vehicular bridge crossing the channel. Velocity was determined by measuring elapsed time taken by weighted floats travelling from the upstream to the downstream edge of the bridge. The cross section was determined by pole sounding. Total channel flow was found to be 33 cubic feet per second. It was noted that most of the channel was choked with aquatic vegetation especially at the confluence with the South Channel.

In 1968, all sections were lead-line sounded prior to making discharge measurements to establish a standard profile for each section. Twenty-three Price current meters were used on a rotational basis to measure the discharge through the sections. Depending upon the catamaran being used, one of three methods were used to record the panel velocities in the vertical: 1) eleven current meters were suspended simultaneously at each tenth of the depth, and at 1 foot and 1/2 foot above the bottom; 2) four current meters were placed at various depths and three different settings covered the full range of depths, namely, 0.1, 0.4, 0.4, 0.7/ 0.2, 0.4, 0.5, 0.8/ 0.3, 0.4, 0.6, 0.9; and 3) three current meters were used, being reset three separate times, as follows, 0.1, 0.4, 0.7/0.2, 0.5, 0.8/0.3, 0.6, 0.9.

At the Chematogan Channel Section, observations were made at the 0.2 and 0.8 depths of the section. The velocities across the section were also sampled, to define the shape of the transverse velocity curve.

As an experiment, during this series of measurements at the Chematogan Channel Section, a different method of measuring discharge was tested; that is, the color-velocity method. This method consisted of injecting a substance into the stream and recording, at some point or points downstream, the time the leading edge of the substance arrived at the recording station.

The direction of flow past the Bassett, Chenal Ecarté and Roberts Landing Sections was ascertained by making a drogue study at each of these sections. Similar drogue studies were made at the Middle, Southeast Bend and South Channel Sections in 1963, and were used for this survey. The flow in the St. Clair Cutoff and Chematogan Channel Sections was assumed to be perpendicular to the section line.

4.15.4 Discharge Computation.

Discharge computations for the conventional measurements were performed by computer, using the Corps of Engineers discharge measurement reduction program. A short description of the methods used in the program is given in Appendix A. The results of the 1963 discharge measurements can be found in file 3-4019 of the U.S. Lake Survey Archives (available at the U.S. National Oceanic and Atmospheric Administration/National Ocean

Service Silver Springs, Maryland). Tables 4.56 to 4.62 (see Appendix C) summarize these measurements. The results of the 1968 measurements can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file 72-1, of the Detroit District, Corps of Engineers, Detroit, Michigan. Tables 4.63 to 4.71 (see Appendix C) summarize the computed discharges.

The measurements made at the Chematogan Channel Section, using the color-velocity method, were documented in the U.S. Lake Survey Miscellaneous Paper 70-1, "Color-velocity Method in Measuring Discharge," by I. M. Korkigian and T. E. Ottenbaker, June 1969. This method is also discussed in the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data's report, "Discharge Measurement Procedures on the Great Lakes Connecting Channels and the International Section of the St. Lawrence River," dated October 1991. Table 4.72 (see Appendix C) summarizes these measurements and compares them with measurements made at the same time using current meters.

4.16 Roberts Landing Section, 1971.

4.16.1 Purpose.

Two series of discharge measurements were made at the Roberts Landing Section, in 1971, both testing new methods of making these measurements. One series of measurements employed a new "moving-boat" technique, which was being developed by the U.S. Geological Survey. The second series of measurements were made using a continuous-recording submerged current meter, a Plessey current meter. Both of these series of measurements were conducted by the Detroit District, Corps of Engineers. Unfortunately, no reliable data were obtained from either series. Concurrent to the measurements being made at the Roberts Landing Section, measurements using these same two techniques were being made on the Detroit River at the Fort Wayne Section.

4.16.2 Description of Section.

The Roberts Landing Section was originally established in 1968 and recovered for this survey. For the section description, see Subsection 4.15.2. The section was divided into 19 panels. Between January 11 and February 26, 1971, a series of 62 measurements were made at this section, using the moving-boat technique. The Plessey current meter, for the submerged current meter measurements, was installed at the section on December 14, 1970 and removed on April 16, 1971.

The approximate location of this discharge measurement section is shown on Figure 4-7.

4.16.3 Measurement Techniques.

The moving-boat series of discharge measurements involved taking measurements

while a velocity meter suspended from a boat was moved across the panels. Records concerning this particular series of measurements are very sparse. However, a general description of this technique can be found in the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data's report, "Discharge Measurement Procedures on the Great Lakes Connecting Channels and the International Section of the St. Lawrence River," dated October 1991.

To perform the submerged current meter measurements, the Canadian Center for Inland Waters loaned the Detroit District, Corps of Engineers, two Plessey current meters, Model 21. One was placed in the St. Clair River, the other was used for a similar series of measurements in the Detroit River. A study was made to determine where the submerged current meters should be placed in order to collect the most significant data. The current meters had to be placed at a panel point; that was the only point where previously measured data were recovered. It was also necessary that the current meters be installed deep enough so that no deep-draft vessels could collide with them in the shipping lane. Since the current meters have self-contained magnetic tape recorders, it was not necessary to run a cable to the shore for monitoring purposes. In this respect, transverse positioning of the current meter on the section was of little consequence.

4.16.4 Discharge Computation.

Unfortunately, most of the records of these measurements were lost and little is known of the exact way the data were reduced, or the results thereof. What little is documented on this series of measurements is located in the Great Lakes Hydraulics and Hydrology Branch Archives, file 75-71, of the Detroit District, Corps of Engineers, Detroit, Michigan. Due to the minimal amount of data collected from this survey, data tables are not included in Appendix C.

4.17 Roberts Landing and Chenal Ecarté Sections, 1972.

4.17.1 Purpose.

These discharge measurements were conducted to measure the distribution of flow between the main St. Clair River channel and the Chenal Ecarté, under spring ice breakup conditions.

All work for this survey was performed by Detroit District, Corps of Engineers.

4.17.2 Description of Sections.

The **Roberts Landing Section** was recovered from previous surveys. For the section description, see Subsection 4.15.2. The section consisted of 20 panels. A total of three discharge measurements were made during the period March 2 through March 13, 1972.

The **Chenal Ecarté Section** was located near the head of this channel, at the Walpole Bridge. The section extended from the Canadian mainland to Walpole Island, and was divided into six panels. Six measurements were made at the section, between March 7 and March 13, 1972.

The approximate locations of these discharge measurement sections are shown on Figure 4-7.

4.17.3 Measurement Techniques.

Velocity observations were made at each tenth of the depth of the panels using three current meters lowered in a series of three settings. Only selected panels were metered at the Roberts Landing Section, during each measurement.

4.17.4 Discharge Computation.

The measurements at the Chenal Ecarté Section were reduced using the Detroit, District, Corps of Engineers' discharge measurement reduction program. This program is briefly described in Appendix A. Table 4.73 (see Appendix C) summarizes these measurements.

The final discharge computations for the Roberts Landing Section measurements could not be found, but some of the raw data are on file. The recovered data from the 1972 measurements of the Roberts Landing and Chenal Ecarté Sections are located in the Great Lakes Hydraulics and Hydrology Branch Archives, file 72-24, of the Detroit District, Corps of Engineers, Detroit, Michigan.

4.18 St. Clair and Dry Dock Sections, 1973.

4.18.1 Purpose.

This program was undertaken to measure the high flows in the St. Clair River resulting from extremely high levels on the Great Lakes in 1973. These measurements were used to develop updated rating equations for computing the St. Clair River monthly mean flow. The data gathered in this survey were also used in the development of an unsteady-state flow model for the St. Clair River.

Measurements at the St. Clair Section were carried out by the Detroit District, Corps of Engineers. The Water Survey of Canada performed the measurements at the Dry Dock Section.

4.18.2 Description of Sections.

The **St. Clair Section,** established in 1944, was recovered for this survey. The section was located about 3.2 miles downstream from the Pine River, located in the City of St. Clair, Michigan. The section was divided into 16 panels. Twenty-six discharge measurements were made between June 18 and July 10, 1973. See Figure 4-4 for the location of this section.

The **Dry Dock Section** was first established in 1901 and was recovered from previous surveys. For the section description, see Subsection 4.10.2. The section was divided into 16 panels, for this survey. A total of 19 discharge measurements were made during the period June 20 to July 11, 1973. See Figure 4-2 for the approximate location of this section.

4.18.3 Measurement Techniques.

Both sections were echo sounded prior to the taking of discharge measurements. The St. Clair Section was also lead-line sounded.

Drogue surveys were conducted at the two sections, to determine the direction of flow.

For the purpose of vertical control at the St. Clair Section, water levels were recorded by a digital recording gauge, temporarily installed 50 feet downstream from the section line. The gauge was referenced to bench marks "Russ" and "Nora" (584.97 and 597.91 feet, IGLD 1955, respectively). Water levels for the Dry Dock Section were recorded at the Dry Dock gauge, a permanent gauge located 20 feet above the section line.

The same method of taking discharge measurements was used at both sections. The Detroit, District, Corps of Engineers, used Price current meters. The Water Survey of Canada used Gurley Price pattern 622AA current meters. Each measurement consisted of two-minute observations of velocity at each tenth of the depth of each panel. To measure the discharge through a panel, four meters were used simultaneously. One meter was held constant at the 0.4 depth. The remaining three meters measured velocities at each tenth of the depth in a series of three settings.

4.18.4 Discharge Computation.

The data collected were reduced to discharges by the respective agencies, using computer programs. The program used by the Detroit District, Corps of Engineers, is described in Appendix A.

Tables 4.74 and 4.75 (see Appendix C) summarize the results of this project. Data and reports from this survey can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file 74-5, of the Detroit District, Corps of Engineers, Detroit, Michigan.

4.19 Meuller Brothers Section, 1976.

4.19.1 Purpose.

The section was established and discharge measurements were made as part of a study to sample sediment loading in the upper portion of the St. Clair River. The survey was carried out by the Water Survey of Canada.

4.19.2 Description of Section.

The Meuller Brothers Section was established just downstream of the Grand Trunk Railroad tunnel, near the Meuller Brothers Ltd. facilities, Sarnia, Ontario. The section was divided into 11 panels. Only two measurements were made, one on May 26 and the other on May 27, 1976.

The location of this discharge measurement section is shown on Figure 4-8.

4.19.3 Measurement Techniques.

The section was echo sounded prior to the beginning of the discharge measurements. Water levels were read from a board gauge referenced to an arbitrary datum. Velocities were measured at the 0.2 and 0.8 depths of each panel.

4.19.4 Discharge Computation.

For each measurement, the velocities measured at the 0.2 and 0.8 depths were averaged to get the vertical velocity for the panel. This averaged velocity was multiplied by the area of the panel to get the discharge through the panel. Panel discharges were added to get the discharge through the section.

Table 4.76 (see Appendix C) lists the results of this discharge survey. Data pertaining to this survey can be obtained from the Water Survey of Canada, Ontario Region, Water Resources Branch, Guelph, Ontario.

4.20 Bay Point Section, 1977 and 1985.

4.20.1 Purpose.

These discharge measurements were obtained to provide additional data for evaluating the existing regimen of the St. Clair River, testing and calibrating the St. Clair River math model and field testing the digital data system on board the Korkigian, the Detroit District, Corps of Engineers' survey vessel .

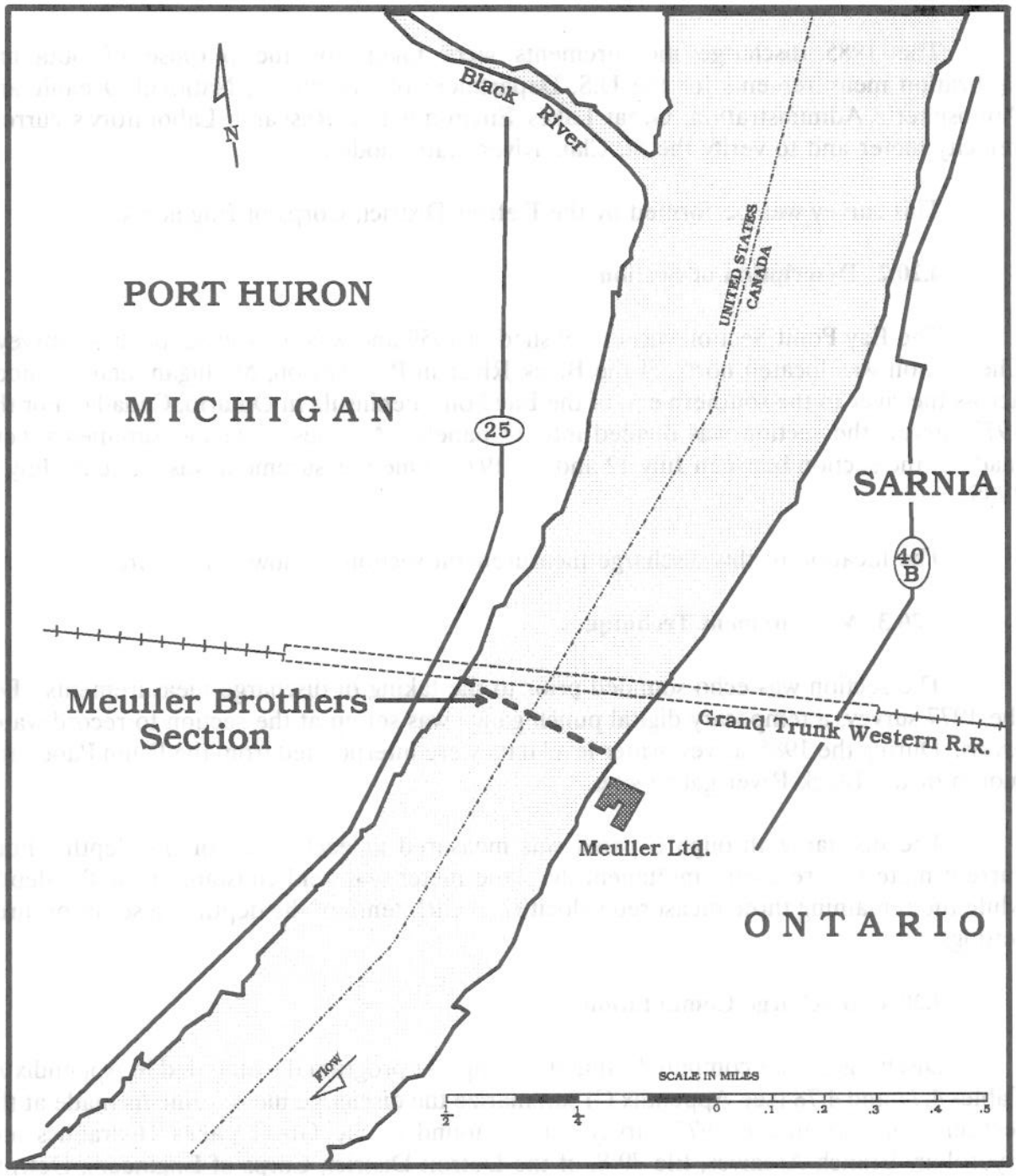

Figure 4-8

St. Clair River, 1976 Meuller Brothers Section Location

The 1985 discharge measurements were taken for the purpose of obtaining calibration measurements for the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory's current velocity meter and to verify the St. Clair River math model.

This survey was performed by the Detroit District, Corps of Engineers.

4.20.2 Description of Section.

The Bay Point Section was established in 1959 and was recovered for these surveys. The section was located north of the Black River in Port Huron, Michigan, and extended across the river to the southern end of the Bay Point Peninsula in Ontario, Canada. For the 1977 survey, the section was divided into 17 panels. A series of 11 measurements were made at the section between July 12 and 28, 1977. One measurement was made on July 5, 1985.

The location of this discharge measurement section is shown on Figure 4-6.

4.20.3 Measurement Techniques.

The section was echo sounded prior to the taking of discharge measurements. For the 1977 survey, a temporary digital punch gauge was set up at the section to record water levels. During the 1985 survey, water level data were interpolated from the Dunn Paper and mouth of the Black River gauge sites.

The discharge through a panel was measured at each tenth of the depth. Four current meters were used simultaneously. One meter was held constant at the 0.4 depth, while the remaining three measured velocities at each tenth of the depth in a series of three settings.

4.20.4 Discharge Computation.

Discharges were computed using the computer program documented in Appendix A. Tables 4.77 and 4.78 (see Appendix C) summarize the discharge measurements made at the section. Data from the 1977 survey can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file 79-8, of the Detroit District, Corps of Engineers, Detroit, Michigan. The raw data for the 1985 discharge measurements can be found in the Branch's Archive file 91-28.

4.21 East Stag Island and West Stag Island Sections, 1981.

4.21.1 Purpose.

The purpose of this set of measurements was to measure the flow around Stag Island.

The measurements were carried out by the Great Lakes Hydraulics and Hydrology Branch of the Detroit District, Corps of Engineers.

4.21.2 Description of Sections.

The **East Stag Island Section** was located near the center of Stag Island and extended from Stag Island to the Canadian shore. The section was divided into five panels. A series of 3 discharge measurements were made between July 29 and July 31, 1981.

The **West Stag Island Section** was located near the center of Stag Island and extended from Stag Island to the American mainland. The section was divided into five panels. A series of 4 discharge measurements were made between July 29 and July 31, 1981.

The locations of these discharge measurement sections are shown on Figure 4-9.

4.21.3 Measurement Techniques.

The same basic method was used to meter these sections as was used on previous surveys. Four Price current meters were suspended from the survey vessel. One meter was kept at the 0.4 depth as an index meter. The remaining three meters collected readings at the nine-tenth depths.

4.21.4 Discharge Computation.

The data collected by the U.S. were processed on a digital computer, using the Detroit District's discharge measurement program.

These measurements are summarized in Tables 4.79 and 4.80 (see Appendix C). The raw data can be obtained from the Great Lakes Hydraulics and Hydrology Branch Archive, file number GLHH 91-22, of the Detroit District, Corps of Engineers, Detroit, Michigan.

4.22 GLERL Verification Section, 1979 Through 1985.

4.22.1 Purpose.

Discharge measurements were taken at periodic intervals, over a seven year period, by the Detroit District, Corps of Engineers, to provide a calibration reference for a current velocity meter installation of the Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration, and to further verify the St. Clair River mathematical model.

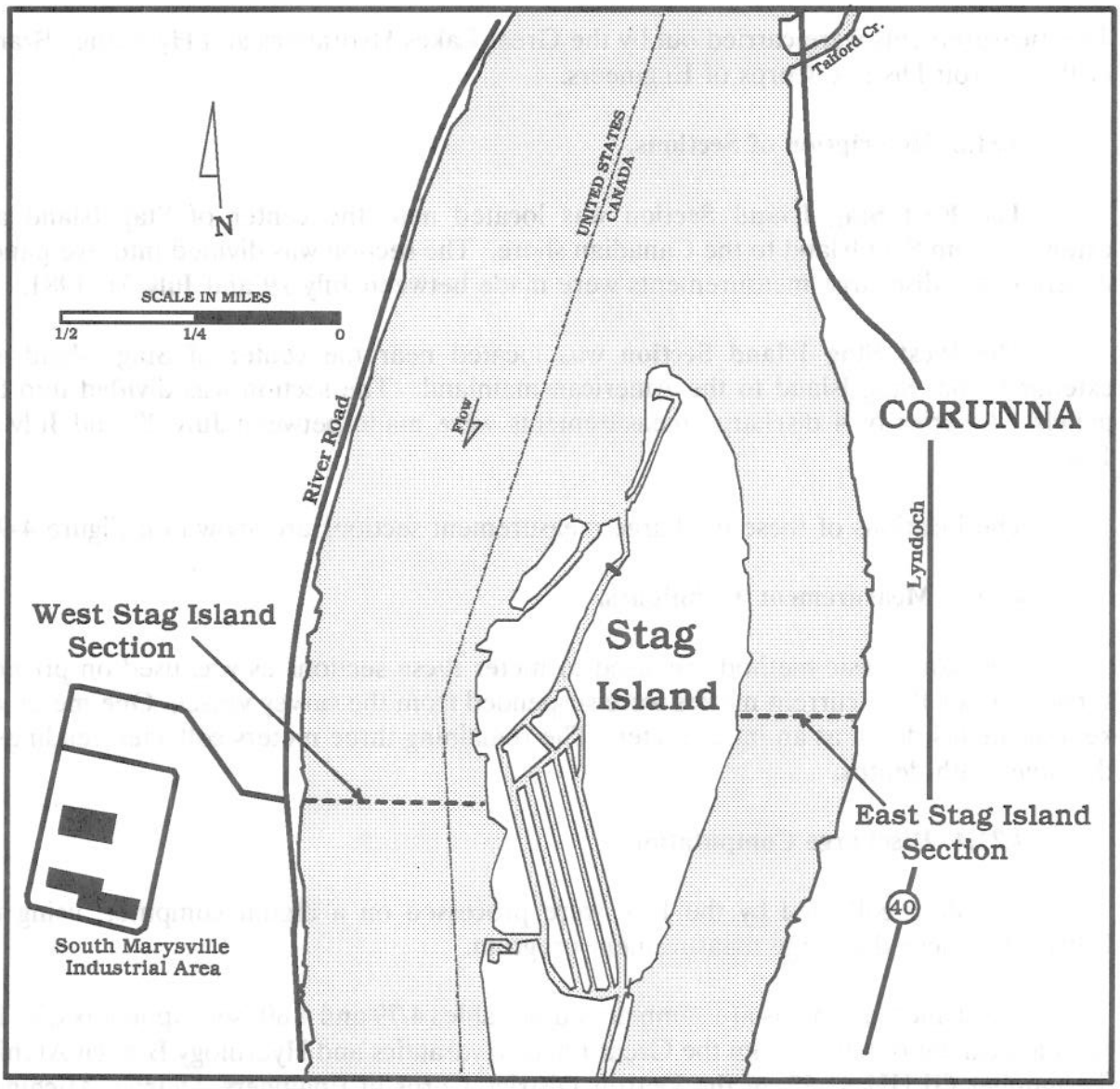

Figure 4-9

St. Clair River, 1981 East Stag Island and West Stag Island Section Locations

4.22.2 Description of Section.

The GLERL Verification Section was established, during the fall of 1979, at a site near the northern end of an old pump station building located at the Port Huron Water Filtration Plant (at Pine Grove Park), Michigan, and extending across the river to the Bay Point Peninsula, Ontario. Analysis of soundings led to the selection of a 19 panel distribution for the discharge section, which was maintained for subsequent measurement sequences through June 1984. To accommodate changes in the flow distribution patterns near the Canadian and U.S. shorelines, panels 18 and 19 were combined for the November 1984 measurements and panels 1 and 2 were combined for the October 1985 measurements. Measurements were made on November 16, 1979; six between October 7 and October 15, 1981; on May 10, 1982; four between May 18 and May 24, 1983; five between November 30 and December 6, 1983; five between June 5 and June 11, 1984; five between November 27 and December 3, 1984 and four between October 15 and October 18, 1985. Unsuccessful attempts to collect discharge data were made on November 17, 1979, May 5 and May 7,1982 and June 25 and June 26, 1985.

The location of this discharge measurement section is shown on Figure 4-10.

4.22.3 Measurement Techniques.

During November, 1979, soundings were made, at the verification section, along a line corresponding to a submerged meter location. Water level information for the 1979 measurements was taken from a temporary gauge installed at the U.S. Coast Guard dockage, approximately 600 feet downstream of the section location. For all of the other measurement sequences, data were obtained from the Point Edward, Ontario, gauge and from the Dunn Paper, mouth of the Black River and Dry Dock, Michigan, gauges, as recoverable.

The discharge through a panel was measured at each tenth of the sounded depth. Four current meters were used simultaneously; one was held constant at the 0.4 tenth depth, while the others measured velocities at each tenth setting in a series of three settings (the 1981 measurements did not utilize an index meter, due to equipment malfunction). Directional coefficients were derived from current directional and velocity samples at the 0.2, 0.4 and 0.8 of the total depth, utilizing an electromagnetic current meter.

4.22.4 Discharge Computation.

Discharges were computed using the Corps of Engineers computer program documented in Appendix A. Table 4.81 (see Appendix C) summarizes the measured discharges. Raw data from each of the surveys can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file number 91-28, of the Detroit District, Corps of Engineers, Detroit, Michigan.

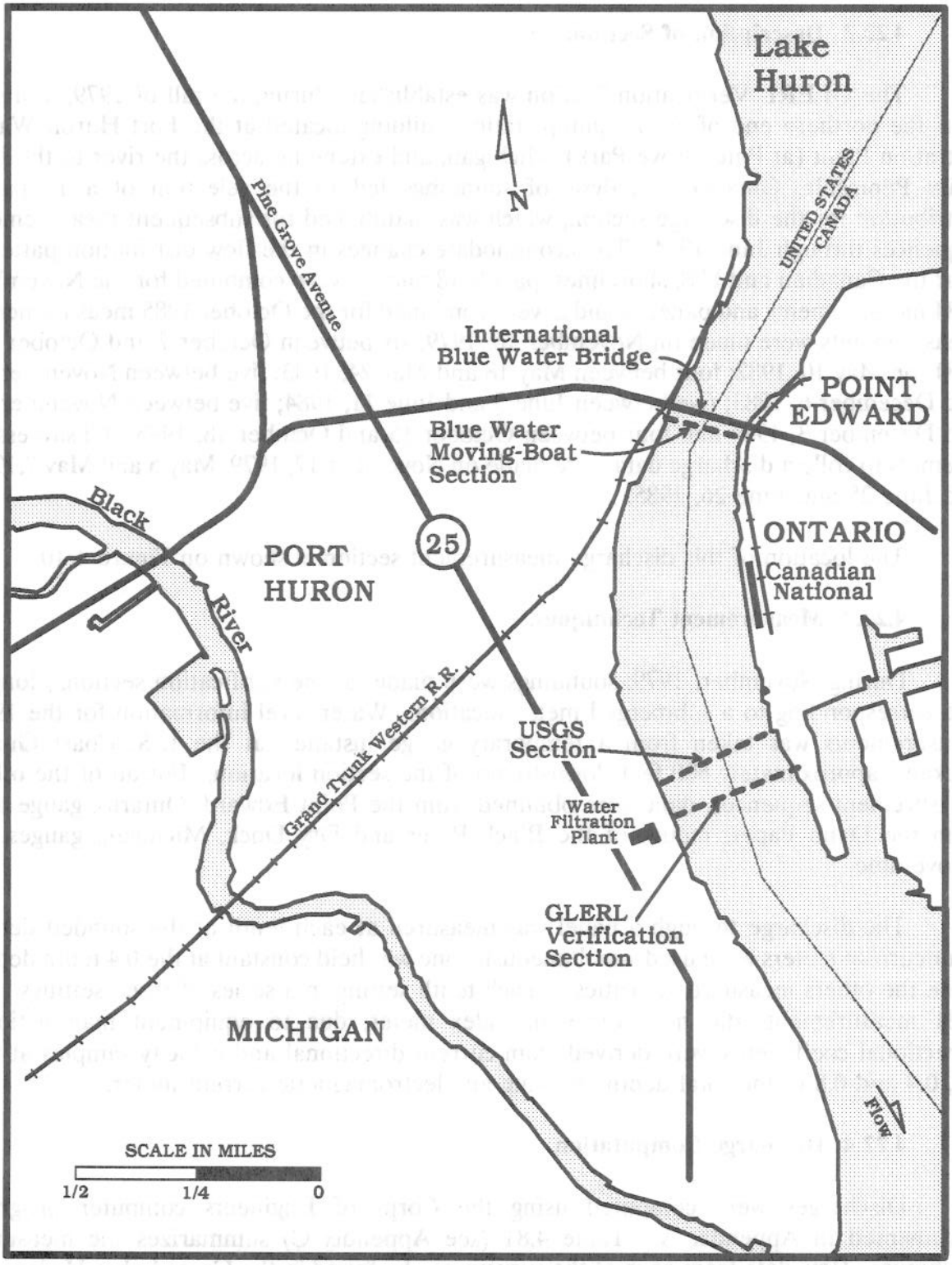

Figure 4-10

St. Clair River, 1979-1985, GLERL Verification, USGS and Blue Water Moving-Boat Section Locations

4.23 USGS and Blue Water Moving-boat Section, 1981 and 1982.

4.23.1 Purpose.

Discharge measurements were taken by the U.S. Geological Survey and the Water Survey of Canada, Ontario Region, at two separate sites, during the October, 1981 GLERL Verification Section measurements (see Subsection 4.22). These measurements were part of an interagency effort to provide a calibration reference for the Great Lakes Environmental Research Laboratory's velocity meter installation, which was utilized for further verification of the St. Clair River mathematical model and for an evaluation between the moving-boat and conventional discharge measurements technology. The Geological Survey unilaterally undertook a series of moving-boat measurements, during May, 1982, to evaluate the hydraulic characteristics of the reach of the St. Clair River near the Environmental Research Laboratory's current meter installation and to provide further data for the current meter's calibration.

4.23.2 Description of Sections.

The **USGS Section** was established, during the October, 1981 measurements, at a site 436 feet north of the pump house building located at the Port Huron Water Filtration Plant, Michigan, starting 30 feet off the shore and ending 115 feet from the Bay Point Peninsula, Ontario. The Water Survey of Canada concurrently established the **Blue Water Moving-boat Section** beneath the Blue Water Bridge, starting/ending 20 feet from either shore. During the May, 1982 measurements, the USGS Section was re-established; also, a new section was established approximately along the GLERL Verification Section.

Five measurements were made, by the U.S. Geological Survey, at the USGS Section, between October 8 and October 9, 1981, while six were made, by the Water Survey of Canada, at the Blue Water Section, between October 14 and October 15, 1981. For the 1982 measurement sequence, the U.S. Geological Survey took five measurements at the USGS Section, between May 4 and May 6, and two measurements at the modified GLERL Verification Section, between May 5 and May 6.

The locations of these discharge measurement sections are shown on Figure 4-10.

4.23.3 Measurement Techniques.

Vertical velocity profiles for the 1981 and 1982 measurements were made at various times during a measurement sequence, using standard Price current meters; evaluations were made of near shore flow, as appropriate. The U.S. Geological Survey installed a temporary staff gauge at the Huron Lightship monument for the 1981 and 1982 measurements; also, a digital recorder was installed in the pump house facility for the 1981 measurements. Wind speed recorders were installed on the Canadian shore, by the U.S.

Geological Survey, for each measurement. The Water Survey of Canada relied on data from the Point Edward, Ontario, gauge for analysis of their discharge results.

All discharge measurements were conducted using the moving-boat technology; the Water Survey of Canada employed a computer controlled discharge processing system, while the U.S. Geological Survey used a semi-automated method requiring a three person crew (boat operator, angle observer and notekeeper/rate counter operator).

4.23.4 Discharge Computation.

Discharges for the above measurements were computed according to the particular moving-boat system in operation. The Water Survey of Canada's system automatically computes the discharge from the depth, angle and current meter inputs, while the U.S. Geological Survey discharges were computed manually from the data marked on the recording forms.

Data from these surveys can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file number 91-28, of the Detroit District, Corps of Engineers, Detroit, Michigan. Tables 4.82 and 4.83 (see Appendix C) summarize the measured discharges.

4.24 Summary of Discharge Measurements.

For easy reference, a matrix of the identifiable historical St. Clair River discharge measurements is provided in Table 4.1. The table contains only basic information in an abbreviated format; therefore, for more information on a particular series of measurements refer to the noted subsection in the table.

TABLE 4.1 Summary of St. Clair River Discharge Measurements

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
North, Middle and South Channels **(See Subsection 4.1)**	Appears to be October 4 - 10, 1856	Not specifically known	St. Clair Flats	Not known	Not Recovered
Near city of St. Clair, MI **(See Subsection 4.2)**	June 20 - July 19, 1867 & June 27 - Sept. 17, 1868	To determine the flow in the St. Clair River	Near the city of St. Clair, MI	Floats (1867); Electrical recording current meters designed from anemometers (1868)	Table 4.1
Dry Dock & **(See Subsection 4.3)**	April 29 - Dec. 6, 1899, June 19, 1900 - Feb. 2, 1901, March 25 - Apr 26, 1901, May 14 - June 28, 1901 & Aug. 12 - Sept. 26, 1902	To measure the total flow in the St. Clair River	2-1/2 miles below mouth of the Black River	Conventional	Tables 4.2, 4.3, 4.5, 4.6, 4.7,
Craig	Feb. 4 - March 23, 1901		Below the Black River, stretched from a dock on U.S. shore at the foot of Baird Street, Port Huron, MI, to a lumber dock in Sarnia Bay, Ontario		Table 4.4
Dry Dock & **(See Subsection 4.4)**	Nov. 7 - 18, 1908 & Nov. 15 - Dec. 7, 1909	To substantiate past flow measurements and to determine if there was any change in the regimen of the St. Clair River since last measurements in 1901	2-1/2 miles below mouth of the Black River	Conventional	Tables 4.8 & 4.10
Gorge	Nov. 18 - Dec. 19, 1908 & Oct. 15 - Dec. 10, 1909		About 1400 ft. below Fort Gratiot Lighthouse and about 1250 ft. above the foot of State Street		Tables 4.9 & 4.11

TABLE 4.1 Summary of St. Clair River Discharge Measurements (cont'd)

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
Gorge, (See Subsection 4.5)	May 9 - Nov. 11, 1910	To determine the distribution of flow through the various channels of the St. Clair River delta, and to ascertain whether the distribution among the channels varied with the seasons	About 1400 ft. below Fort Gratiot Lighthouse and about 1250 ft. above the foot of State Street	Conventional	Table 4.12
Dry Dock,	June 22 - Oct. 1, 1910		2-1/2 miles below mouth of the Black River		Table 4.13
SNY,	May 25 - Nov. 25, 1910		On Chenal Ecarté, below Marshy Creek, about 3/4 mile below main channel of St. Clair River		Table 4.14
Bridge,	May 26 - Nov. 25, 1910		Across head of South Channel of St. Clair River, from west shore of Walpole Island to east shore of Russell Island		Table 4.15
Bassett,	June 8 - Nov. 28, 1910		From Bassett Island northeast to Squirrel Island, at head of Bassett Channel		Table 4.16
Southeast Bend,	June 2 - Nov. 26, 1910		From Bassett Island to Harsens Island, across the Southeast Bend Channel		Table 4.17
Middle Channel &	May 28 - Nov. 19, 1910		From Dickenson Island to Harsens Island, across the Middle Channel		Table 4.18
Salt Block	June 4 - Nov. 22, 1910		From Dickinson Island to the Michigan mainland, across the North Channel		Table 4.19

TABLE 4.1 Summary of St. Clair River Discharge Measurements (cont'd)

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
Dry Dock **(See Subsection 4.6)**	Nov. 22, 1924 - Aug. 22, 1930	To provide base data for St. Clair River stage-discharge equations	2-1/2 miles below mouth of the Black River	Conventional	Tables 4.20 - 4.26
Stag Island & **(See Subsection 4.7)**	May 7 & 8, 1925, May 16 - Oct. 18, 1928 & May 21 - Sept. 13, 1929	To determine the distribution of flow around Stag and Woodtick Islands	Lower end of the island; east channel	Conventional	Table 4.27
Woodtick	May 9 - Oct. 24, 1928 & May 15 & 17, 1929		2600 ft below head of the island; east channel		Table 4.28
Dry Dock & **(See Subsection 4.8)**	May 18 - Oct. 12, 1937	To reflect a change, if any, in the discharge capacity of the channel, due to dredging	2-1/2 miles below mouth of the Black River	Conventional	Tables 4.29 - 4.30
Stag Island	Oct. 14 - 19, 1937 & July 17 - 20, 1944		Lower end of the island; east channel		Tables 4.31-4.32
St. Clair **(See Subsection 4.9)**	June 8, 1944 - Sept. 29, 1950	To provide data after the completion of a project to provide 24 ft. navigation depths	3.2 miles below the Pine River at St. Clair, MI	Conventional	Tables 4.33 - 4.39

TABLE 4.1 Summary of St. Clair River Discharge Measurements (cont'd)

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
Dry Dock, (See Subsection 4.10)	Aug. 5 - 22, 1947	Not specifically known	2-1/2 miles below mouth of the Black River	Conventional	Table 4.40
Stag Island &	July 21 - 28, 1947		Lower end of Stag Island; east channel		Table 4.41
North Channel	Oct. 9 - 17, 1947		6 miles below Algonac, MI, approximately 1000 ft below Old Salt Block Section		Table 4.42
St. Clair (See Subsection 4.11)	Aug. 11 - 18, 1952	To determine the total flow in the St. Clair River at a time of extreme high water levels on Lake Huron	3.2 miles south of Pine River in St. Clair, MI	Conventional	Table 4.43
St. Clair (See Subsection 4.12)	Feb. 7 - March 5, 1953	To evaluate the regular U.S. Lake Survey method of measuring discharge under winter conditions and to determine whether the flow past a calibrated section could be ascertained from only 1 to 3 index points	3.2 miles south of Pine River in St. Clair, MI	Conventional	Table 4.44
Blue Water (See Subsection 4.13)	Jan. 16 - March 15, 1954	To test an alternate method of measuring the winter discharge of the St. Clair River	At the Blue Water Bridge, between Port Huron, MI and Sarnia, Ontario	Bridge	Table 4.45
Bay Point (See Subsection 4.14)	July 28, 1959 - July 10, 1968	To monitor the St. Clair River outflow regimen as dredging of the 27-foot deep navigation channel progressed	North of Black River, near foot of Rawlins Street in Port Huron, MI., extended across St. Clair River to southerly end of Bay Point Peninsula, Ontario	Conventional	Tables 4.46 - 4.55

TABLE 4.1 Summary of St. Clair River Discharge Measurements (cont'd)

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
Roberts Landing, (See Subsection 4.15)	July 17 - Aug. 16, 1968	To determine the distribution of flow through the various channels of the lower St. Clair River	Above the confluence of the Chenal Ecarté, from a point near Roberts Landing MI, to Canadian shore near Port Lambton	Conventional	Table 4.63
North Channel,	July 8 - 17, 1963 & July 17 - 23, 1968		Lower portion of the North Channel extending from U.S. mainland to Dickinson Island		Tables 4.56 & 4.64
Middle Channel,	July 24 - 30, 1963 & July 17 - 23, 1968		At head of Middle Channel, from Dickinson Island to Harsens Island		Tables 4.57 & 4.65
Chenal Ecarté,	Aug. 16 - 20, 1963 & Aug. 12 - 16, 1968		4500 ft downstream from head of this channel, extends from Canadian mainland to Walpole Island		Tables 4.58 & 4.66
South Channel,	Aug. 5 - 15, 1963 & Aug. 12 - 16, 1968		Head of the South Channel, from Walpole Island to Russell Island		Tables 4.59 & 4.67
St. Clair Cutoff,	Aug. 27 - Sept. 16, 1963 & July 26 - Aug. 3, 1968		Head of St. Clair Cutoff Canal, from Seaway Island to Bassett Island		Tables 4.60 & 4.68
Southeast Bend,	Aug. 28 - Sept. 18, 1963 & July 26 - Aug. 3, 1968		Head of Southeast Bend of the South Channel, from Harsens Island to Seaway Island		Tables 4.61 & 4.69
Bassett Channel &	Sept. 17 - 21, 1963 & Aug. 6 - 9, 1968		3000 ft downstream from the head of Bassett Channel, from Bassett Island to Squirrel Island		Tables 4.62 & 4.70
Chematogan Channel	Aug. 6 -10, 1968		Near the head of Chematogan Channel		Tables 4.71 & 4.72

TABLE 4.1 Summary of St. Clair River Discharge Measurements (cont'd)

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
Roberts Landing **(See Subsection 4.16)**	Jan. 11 - Feb. 26, 1971	To test the "moving-boat technique" for discharge measurements, also the use of the Plessey current meter	Above the confluence of the Chenal Ecarté, from a point near Roberts Landing MI, to Canadian shore near Port Lambton	Moving-boat	Not Recovered
Roberts Landing & **(See Subsection 4.17)**	March 2 - 13, 1972	To measure the distribution of flow between the main St. Clair River channel and the Chenal Ecarté, under spring breakup conditions	Above the confluence of the Chenal Ecarté, from a point near Roberts Landing MI, to Canadian shore near Port Lambton	Conventional	Not Recovered
Chenal Ecarté	March 7 - 13, 1972		Near head of this channel, at the Walpole Bridge		Table 4.73
St. Clair & **(See Subsection 4.18)**	June 18 - July 10, 1973	To measure the high flows in the St. Clair River resulting from high levels on the Great Lakes in 1973	3.2 miles south of the Pine River in St. Clair, MI	Conventional	Table 4.74
Dry Dock	June 20 - July 11, 1973		2.5 miles below the mouth of the Black River		Table 4.75
Meuller Brothers **(See Subsection 4.19)**	May 26, 1976 & May 27, 1976	To sample sediment loading in the upper portion of the St. Clair River	Just downstream of the Grand Trunk Railroad tunnel, near Meuller Brothers Ltd. facilities, Sarnia, Ontario	Conventional	Table 4.76

TABLE 4.1 Summary of St. Clair River Discharge Measurements (cont'd)

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
Bay Point **(See Subsection 4.20)**	July 12 - 28, 1977 & July 5, 1985	To provide additional data for evaluating the existing regimen of the St. Clair River; testing and calibrating the St. Clair River math model; field testing the digital data system of the Korkigian (survey vessel)	North of the Black River in Port Huron, MI and extended across St. Clair River to southern end of Bay Point Peninsula in Ontario	Conventional	Tables 4.77 & 4.78
East Stag Island & **(See Subsection 4.21)**	July 29 - 31, 1981	To measure the flow around Stag Island	Near the center of Stag Island, extending from Stag Island to the Canadian shore	Conventional	Table 4.79
West Stag Island			Near the center of Stag Island, extending from Stag Island to the American mainland		Table 4.80
GLERL Verification **(See Subsection 4.22)**	Nov. 16, 1979 - Oct. 18, 1985	To provide a calibration reference for GLERL's current velocity meter installation, and to further verify the St. Clair River math model	At Port Huron Water Filtration Plant, MI, extending across river to Bay Point Peninsula, Ontario	Conventional	Tables 4.81
USGS and Blue Water Moving-boat 1) USGS Section 2) Blue Water Bridge Section 3) GLERL Verification Section **(See Subsection 4.23)**	Oct. 8 - 15, 1981 & May 4 - 6, 1982	To calibrate GLERL's current velocity meter installation, and to further verify the St. Clair River math model; also, for an evaluation between moving-boat and conventional discharge measurements technology	1) At Port Huron Water Filtration Plant, MI, 436 ft. north of pump house building, extending across river to Bay Point Peninsula, Ontario 2) Beneath Blue Water Bridge, from U.S. shore to Canadian shore 3) Approximately along GLERL verification section (see above)	Moving-boat	Tables 4.82 & 4.83

* See Appendix C (under separate cover)